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BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
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EXPERIMENTAL ANALYSIS OF FRACTURE PATTERNS

BY ERNST CLOOS

(Address of the Retiring President of The Geological Society of America)

ABSTRACT

All existing fractures can be imitated in four scale models which show tension or shear fractures with or without rotational deformation. These four experiments can easily be produced by deforming soft clay which rests on a moving square of wire cloth.

En echelon zones are easily produced by placing clay above the edge of a moving tin plate. Tension and shear fractures open in the flexure zone and are unfailing indicators of relative displacement.

Normal or gravity faults occur preferably above domes and anticlines or other areas of distension. Salt-dome patterns may readily be imitated by pushing a plug into a clay model from below. A systematic study of fracture anomalies may prove useful in the detection of areas of uplift above salt domes.

Longitudinal and transverse normal faults in North dome of the Kettleman Hills are readily imitated in a clay model and may be due to vertical uplift with or without lateral compression. The en echelon arrangement of the Kettleman Hills is probably not due to north-south movement toward a weak zone trending northwest. True en echelon folds would trend west-northwest but not nearly north-northwest. The echelon arrangement may be only the alternation of folds or may be due to northeast-southwest movements, possibly in combination with subcrustal blocks and faults.

The San Andreas-Garlock fault system can be imitated only if considerable rotation has opened the angle between shear planes from near 60° to 90° or to 120°. Asymmetry of the fault pattern suggests clockwise rotation. A more complicated experiment in which three blocks are placed as suggested by Ralph Reed seems to come nearer to a fitting imitation but may still include too large an area.

The value of experimentation lies in experience gained by the experimenter rather than in the exact duplication of known fracture patterns. The intense occupation with mechanical principles and the close visible relationship between cause and effect is sobering as well as stimulating.

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Introduction

The importance of fractures can hardly be exaggerated. Most likely man could not live if rocks were not fractured. The loosening of rocks, formation of soil, and erosion would become next to impossible.

The colorful patterns of geological maps would vanish if rift valleys and mountain blocks did not exist. The Canadian Shield would be a solid monotonous block of gneiss with little relief and no mineralization. Dikes could not intrude, and the beautiful patterns of the Crazy Mountains, the Spanish Peaks, Mull, or Skye would not adorn geological textbooks. Fractures facilitate the rise and concentration of metals. Ground water and petroleum circulate along fractures. The most prominent loci for earthquakes are fractures, and, finally, fractures provide most welcome indicators for crustal deformation.

Geology without fractures would be rather dull, and what would the geologist do if he were without faults when his imagination exceeds his geology?

Fractures have been studied for centuries, and even the most superficial observation led to some attempt to interpret fracture patterns in terms of mechanical principles.

Attempts to imitate fracture patterns in the laboratory date back to the earliest geological experiments. For these, many kinds of materials were used, and pressure boxes were constructed which resulted mostly in individual fractures but rarely in regional patterns.

The first paper I ever read at a national GSA meeting was at Tulsa in 1931 (Cloos, 1933b) where I presented a motion picture of experiments and was given the generous allotment of 25 minutes by the then much less harrassed program committee. Since then I have learned a great deal, and I should like to pass a most enlightening and pleasant experience on to those who are interested.

In the following I will briefly outline the experimental approach which has been developed and used, especially by Hans Cloos (1928–1939), and I will apply it to fracture patterns of interest.

It has been said that structural geology is not as suitable a subject for experimentation as, for instance, the formation of mica under high or low pressure. On the other hand, the average geologist knows less about the formation of joints and faults which he sees in the field than about the geochemistry of mica or feldspar about which he only reads. As to the relevancy of these experiments, I feel that the joint pattern or fold is not so important as the experience gained.

To make an experiment work the experimenter must deliberately create a setup of forces and motions and produce a fault, joint, fold, or a dome. If his first arrangement does not work he must try another one. During this process he will inevitably come to grips with cause and effect. Besides that, experimenting is a good deal of fun.

Outline of the Experiments

General Remarks

A detailed description of the experimental method is beyond this occasion, but a comprehensive paper on the subject will soon be published.

As early as 1937, M. King Hubbert stressed the need for making tectonic models scale models. By this he means that the reduction of the size of an area and the time involved in deformation demands a proportional reduction in the strength of the material used if the model is to resemble nature. In the laboratory granite becomes soft clay.

An excellent substance for scale models is wet clay because its physical properties can be varied by adding water. It fractures and shows the most perfect fracture patterns even if it is as liquid as cream. Clay is also cheap and easily obtainable.

The experiments do not call for elaborate and

expensive equipment. A trowel, a table, a few simple boards, wire cloth, containers, etc., are all that is needed. The most essential equipment is a lively imagination.

The following structures and patterns have been successfully produced: tension and shear joints, normal and reverse faults with slickensides, overthrusts, folds, joint sets, fault troughs, radial and concentrical joint and fault patterns, domes, strands of folds with thrusts, areas of reduced and increased lateral distances, areas of uplift or subsidence, volcanoes, glaciers, and cleavage.

Experimental Fracture Patterns

All existing fracture patterns can be imitated by four fundamental experiments: the formation of either tension or shear fractures under conditions of nonrotational or rotational deformation.

If it is once established at what angles stresses produce fractures, it should be simple to find the direction of stress if a fracture pattern is known. At least it looks that way.

The first two experiments have been carried out by many other observers, but the fact that an experiment has been produced by others need not be a deterrent because, in spite of the repetition which goes on in a chemical laboratory, the freshman in Chemistry 1 learns by repeating what others have done a thousand times before him.

The setup is as shown in Figure 1. Clay is placed on a movable square of wire cloth which is pulled at two opposite corners. The pull is in the diagonal of the square, thus preventing external rotation of the entire system. The clay cake is about 2 inches thick, and the surface is smooth and even. The consistency of the clay is that of soft butter. A column 16–20 inches high would spread at the bottom under its own weight. A circle or a series of circles can be impressed on the surface in order to show the amount and direction of deformation.

If the corners are very slowly pulled part—or the two opposite ones pushed toward the center—deformation begins.

One of two things may happen: If the surface of the clay cake is liberally sprinkled with water, tension joints open perpendicular to the pull, as seen in Figure 1 of Plate 1. The pull is shown by arrows and the deformed ellipse. As deformation continues, the fractures open wider and become more conspicuous. A good example of tension joints is Figure 2 of Plate 1. Rough fractures are oriented north-south, perpendicular to a distinct lineation from west to east.

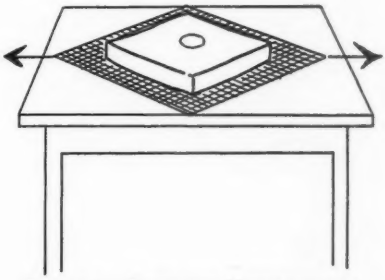

FIGURE 1.—SETUP FOR NONROTATIONAL DEFORMATION
The pull is in the diagnonal of the square net.

Carbonates have filled the fractures and made ridges. In the lower right-hand quadrant the lineation is seen as black dashes, and in a higher layer smaller fractures opened.

If the surface of the clay is not sprinkled with water tension joints will not open in clay experiments. The circle will be more deformed than in the first experiment before fractures appear, but finally small fine lines indicate the position of the long-expected shear fractures.

The angle between the joints is 55°–60°, and it is important to determine that angle before internal rotation has enlarged it. Repetition of the experiment will never change it. This angle agrees very closely with that measured by Hubbert (1951, p. 357) in sand. It is also cited by Billings (1954, p. 164) and has been measured and observed by many others in the field.

If the experiment is continued the fractures become more pronounced, and the angle increases because the fractures rotate. The left shear plane (right lateral according to Hill and Dibblee, 1953, p. 444) rotates counter-clockwise, the right one clockwise, and soon after rotation begins the joints turn into rifts or strike-slip faults (Billings, 1954, p. 212). In Figure 3 of Plate 1 the angle has already increased to 75°. The original circle has become an ellipse and has been faulted. The rotation is symmetrical with respect to the n-s axis of the

experiment. The fractures are vertical. In Figure 4 of Plate 1 internal rotation and faulting have continued, and the angle between faults has increased to 90°.

In due time some fractures become major fracture zones at evenly spaced intervals. They

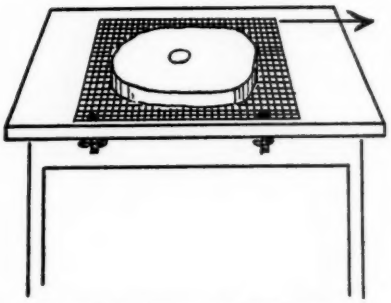

FIGURE 2.—SETUP FOR ROTATIONAL DEFORMATION BETWEEN A COUPLE

The front is bolted to the table, and the rear can move from left to right or vice versa.

may turn into rift zones with en echelon fractures, considerable displacements, and rotation within the zones.

During the entire performance rotation was not external, but the pull remained in the direction of the diagonal of the square of wire cloth. Stress and strain axes remained parallel. Rotation remained within the clay model and symmetrical.

Assuming I had performed the experiment before your arrival, you could by a study of the fracture pattern and its symmetry determine whether external rotation had taken place and therefore whether the principal strain and stress axes had remained parallel during deformation. This would help to determine the direction of the stress component which deformed the clay.

If the experiment is not set up symmetrically and the pull does not coincide with the diagonal of the net but is in a couple, the entire model rotates externally as well as internally, as illustrated in Figure 2.

The same square of wire cloth is placed on the table with its sides parallel to the edges. The front is bolted to the table and the rear can be moved from left to right or right to left. Clay is placed on the wire cloth as before, and the net is moved as indicated by the arrow. Deformation is then accompanied by external rotation. The stress and strain axes will not remain parallel.

Again one of two things may happen: If the surface is sprinkled with water, tension fractures open at an angle of about 45° to the couple (Pl. 2, fig. 1). This kind of fracturing is common in all zones of movement and is well known.

If the surface is left dry, fractures open at the 60-degree angle and also become rifts with the same sense of displacement as in the second experiment (Pl. 2, fig. 2). But, as deformation

PLATE 1.—TENSION AND SHEAR FRACTURES

FIGURE 1.—Tension cracks open if the surface is liberally sprinkled with water.

FIGURE 2.—Tension joints in phyllite layer between limestone beds, South Mountain, Pennsylvania. The joints tore open as irregular cracks perpendicular to a distinct lineation which is parallel to the scale.

FIGURE 3.—Shear fractures open if the clay surface is left "dry". The angle of shearing is less than 60° when the fractures open, but it increases by rotation. The fractures then become rifts which displace the ellipse. The angle is now about 75°.

FIGURE 4.—Same experiment as Figure 3 but a later stage. Displacements of the original ellipse have increased, and the angle between the planes has grown from 60° to 90°.

PLATE 2.—ROTATIONAL DEFORMATION

FIGURE 1.—Rotational deformation. The couple is shown by arrows. Tension joints open at about 45° to the couple if the surface is liberally moistened.

FIGURE 2.—Rotational deformation. Shear joints open at about 60°, but one set is at about 10° to the couple; the other is at about 70° to it.

FIGURE 3.—Rotational deformation between a couple. More advanced stage than Figure 2. Rotation resulted in displacement.

FIGURE 4.—Specimen of phyllite between limestone beds. Clockwise rotational deformation resulted in a faintly visible set of fractures dipping about 35° to the left and a very much stronger set dipping 80° to the right. The angle between the joints is 65°. Scale in millimeters.

TENSION AND SHEAR FRACTURES

FIGURE 2

FIGURE 4

FIGURE 1

FIGURE 3

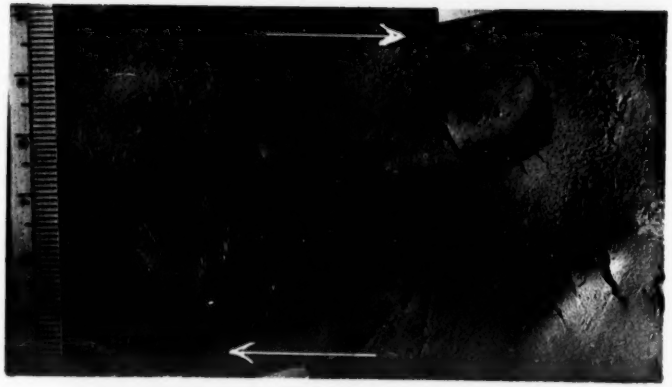

FIGURE 1

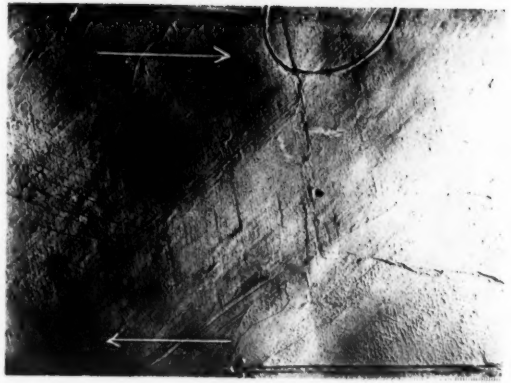

FIGURE 2

FIGURE 3

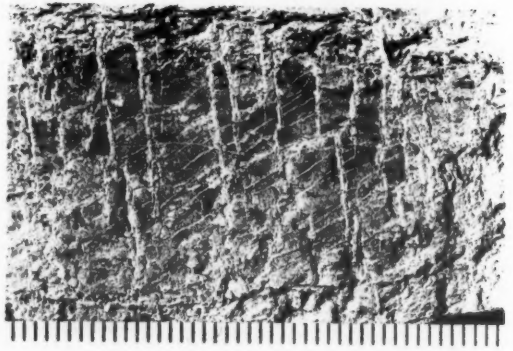

FIGURE 4

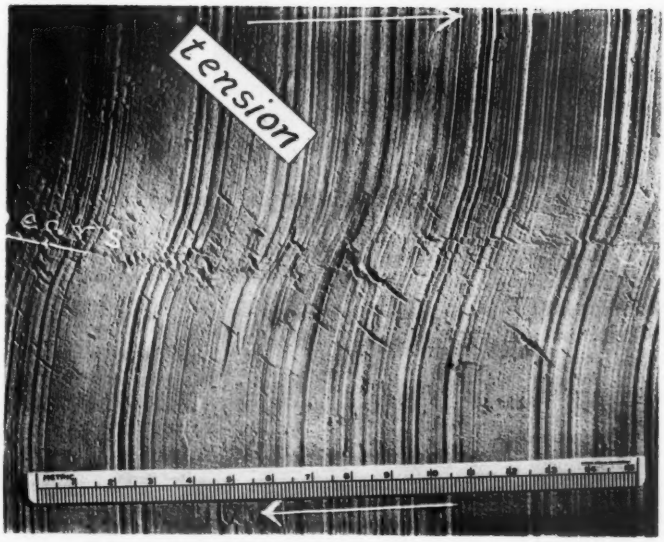

FIGURE 1

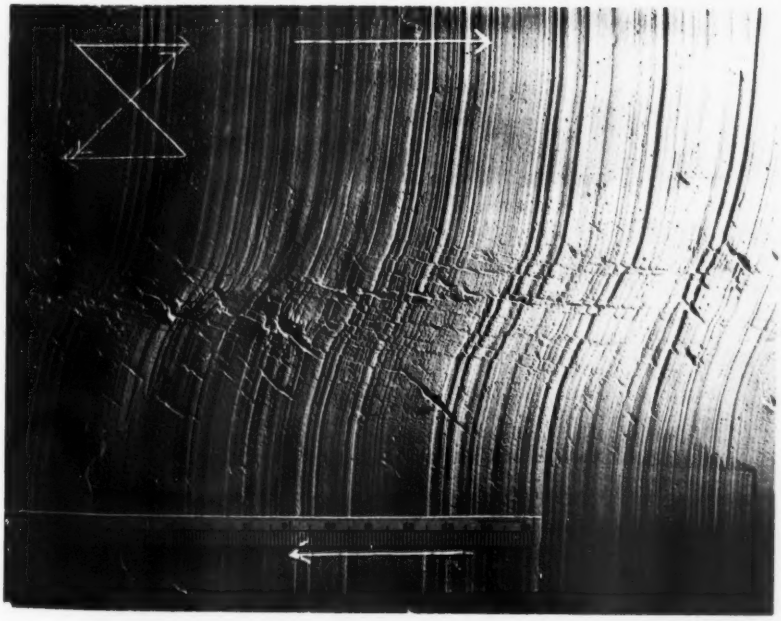

FIGURE 2

EN ECHELON FRACTURES

FIGURE 3

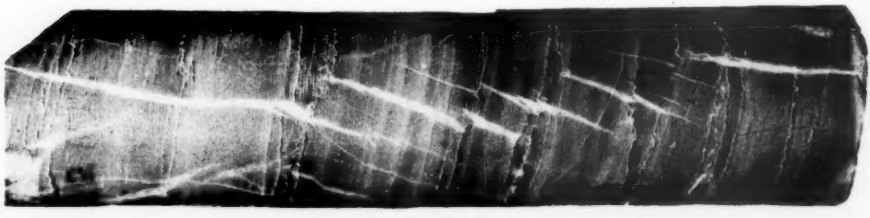

FIGURE 2

FIGURE 1

FEATHER JOINTS AND CHATTER

continues, the two sets of fractures rotate through different angles, and the model will be asymmetrically deformed. One set almost parallels the direction of motion, and the other is at 70°–90° to it. Therefore the two directions show different magnitudes of displacement.

Figure 2 of Plate 2 shows the arrangement of fractures at a fairly early stage of rotational deformation. The camera was in the same position as in the nonrotational experiment, but the ellipse shows the deformation to be by a couple as indicated. One set of fractures opened at a low angle to the pull from left to right, and a second set is almost perpendicular to it. This experiment was photographed earlier than the nonrotational one, and the angle between shear planes is only 65°.

Figure 3 of Plate 2 is a more advanced stage of the same experiment. The steep fractures have now rotated further to the right, and the angle has grown to more than 90°. Those fractures that are at a larger angle to the motion have rotated more than the nearly parallel set. This is shown in the displacement of the ellipse and in the prevalence of these fractures.

If we were again presented with the completed model and had not seen how the deformation had been applied, we could determine the symmetry from the structure pattern and would know that the deformation was accompanied by external rotation.

Rotational deformation is by far the most common kind, particularly in all folded regions. Figure 4 of Plate 2 shows a specimen of fractured phyllite between limestone beds. Two fracture directions are readily visible, but one is very much more prevalent than the other. The lesser set of fractures dips 35° to the left, the more obvious set 80° to the right. The angle between the fractures is 65°. Clockwise rotation follows from the inequality of the fractures and the increased angle.

These four experiments include all kinds of fractures that occur in nature—namely, tension and shear fractures with or without rotation. With such experiments one can establish the angle of shearing, the sense of displacement, the difference between nonrotational and rotational deformation, and the direction of the stress component with respect to the deformation.

One may question the value of the premises of scale models or fail to see the application in nature, or doubt that the angles are the ones observed in granite, sandstone, or shale, but in my opinion the experiments are worth the experience of seeing fractures open, rotate, and grow into faults in response to stresses which can be seen and measured. The great value lies in the fact that cause and effect are closely related from beginning to end.

Applications

General Remarks

Time does not permit descriptions of many applications, but I have chosen a few which have received much attention and are of theoretical as well as practical interest. In passing I will mention en echelon fractures, then turn to the problems of normal faults and salt domes, then to the Kettleman Hills, and finally to the San Andreas Rift. In this way I will proceed from the simple to the complicated, from the small area to the large, and from a perfect fit to one where I must call on your imagination and maybe even good will. It is not accidental

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PLATE 3.—EN ECHELON FRACTURES

FIGURE 1.—En echelon zone in clay experiment. Heavy lines from north to south are trowel marks which have been displaced as indicated by arrows. Dark gashes at angle of 45° are tension joints. Shears barely begin to form almost parallel with couple.

FIGURE 2.—More advanced stage of Figure 1. Shears show displacement of trowel marks to the right. Tension fractures are larger and wider. The second direction of shearing did not open.

PLATE 4.—FEATHER JOINTS AND GRABEN

FIGURE 1.—Feather joint zones in limestone (from Shainin, 1950).

FIGURE 2.—En echelon feather joints in 1¼ inch core of limestone. Kinzers dolomite, Thomasville, Pennsylvania.

FIGURE 3.—Photograph of graben experiment above tin plate as illustrated in Figure 3B. Many faults are restricted to a narrow area. Both shear planes occur, dipping to the left and to the right.

that the small areas provide the better fit. Our scale models include regions which are homogeneously deformed, and if analogies are attempted on too large a unit of the earth's crust we exceed the scale of the model.

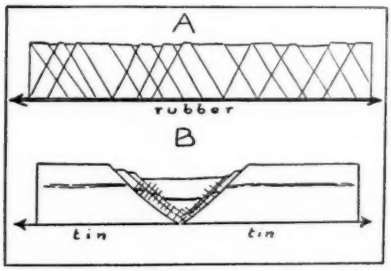

FIGURE 3.—DRAWING OF GRABEN EXPERIMENT

Experiment A: Clay is extended evenly above a rubber base; many smaller and steeper faults occur in the entire clay cake.

Experiment B: Clay is extended above two tin plates which are pulled away from each other. Deformation is localized in a narrow area; fewer faults appear, displacements are larger, and the dip is gentler owing to rotation of the shear planes.

Fault and Flexure Zones

If two blocks move past each other along a fault or flexure, friction causes drag in the adjacent areas (Pl. 3, fig. 1). Owing to the drag tension fractures open, and these are commonly filled with calcite or quartz. A zone of such en echelon fractures parallels the fault and permits determination of the sense of displacement. Such zones are easily produced in an experiment. If the clay surface is kept wet tension fractures will open most readily.

In addition, low-angle en echelon shear fractures open not quite parallel to the trend of the zone of displacement but at an angle of 8°–15° to it. Since deformation is rotational the two shear fractures are unequal in size and displacement. One of them determines the trend or dip of the faults in the zone, and this explains why one fault can only rarely be traced very far but dies out and new ones form parallel and next to it along the general trend.

Figure 1 of Plate 3 shows such a zone in an experiment where the top has moved to the right, relative to the bottom. The heavy lines running north-south are due to small particles of dry clay on the trowel edge when the clay surface was smoothed. The lines were straight at the beginning and show displacement. The wide open short gashes occur only in the flexure zone, and the areas above and below the zone are unaffected.

Left shear planes can also be seen as rifts almost parallel to the direction of movement.

Figure 2 of Plate 3 is a second stage of the same experiment; the fractures are now larger and wider. The displacements on the left shear planes are more marked. The scale shows centimeters and millimeters.

Figure 1 of Plate 4 is a copy of an illustration by V. E. Shainin (1950, Pl. 1, fig. 3) from a limestone area in Virginia. White, calcite-filled gash veins occur in en echelon zones which intersect at low angles. Such zones are extremely common in the Appalachian limestones, and they indicate the sense of movement very well and are of considerable commercial significance. In drilling for high-grade limestone one frequently meets fractured limestone and calcite veins. If these are arranged in en echelon zones as shown in Figure 2 of Plate 4 they do not necessarily indicate large displacements, even if they appear to be rather dominant. Figure 2 of Plate 4 is of a core of limestone which penetrated an en echelon zone. White short calcite veins and bedding planes with stylolites indicate the sense of relative displacement which is to the right along the scale and to the left along the other side of the core.

Normal or Gravity Faults

If the second experiment—nonrotational deformation with shear planes—is thought of as a cross section instead of a map, gravity will become an important factor, and the rifts become gravity or normal faults. Normal faults which dip less than 90° are very common but can open only where the distance between two points on the earth's surface has increased in areas of lateral extension.

Normal faults are easily produced if a clay model is distended laterally as shown in Figure 3. This can be done on a rubber base which is pulled sideways as shown in Figure 3A or on two tins which are pulled away from each other as shown in Figure 3B. On the rubber base the extension is distributed equally over the entire

length of the model, and the individual fractures are small and steeper because the rotation of the individual faults is less.

If two tins are used the deformation is limited to the area above the edge of the tins, and the individual faults are much larger. The faults rotate more because there are fewer and the dip becomes gentler.

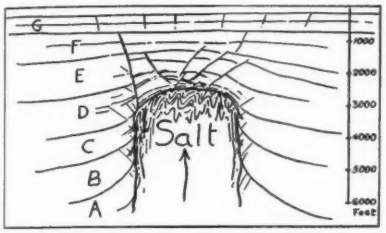

FIGURE 4.—THEORETICAL CROSS SECTION THROUGH A RISING SALT DOME

The lower formations are completely pierced by the salt dome, the intermediate formations are only domed, the uppermost ones still unaffected.

Figure 3 of Plate 4 shows the effect of lateral pull if two tin plates are used. The normal faults dip toward each other and define a fault trough between them. Examples for this kind of faulting and graben formation are legion, and the problem was thoroughly discussed by Hans Cloos in 1939.

It is rather remarkable that the graben subsides in spite of the unyielding table top below the clay. Subsidence is made possible by lateral withdrawal of clay and rotation of the shear planes, very similar to the rotation in the experiments mentioned before.

In nature the lateral pull is supplied by distension in areas of uplift, and normal faults are most common in areas of upwarp, as for instance above salt domes.

Structures above Salt Domes

A salt dome is but a very slender plug, almost a needle, which pushes upward into the uppermost layers of the crust. It enters slightly consolidated or unconsolidated sediments, pushes them aside and upward, and is mostly stuck fast, seemingly frozen where we now find it.

Fracture patterns near or above salt domes are of more than academic interest because they provide circulation or traps for migrating oil. If the domes are still moving or have moved rather recently, their fracture patterns differ markedly from prevailing regional trends. It would therefore seem useful to find out what fracture patterns indicate rising domes and then to study fractures in the field with an eye toward patterns which are typical for domes.

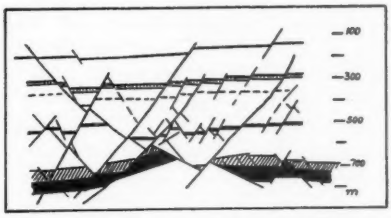

FIGURE 5.—PROFILE ABOVE SALT DOME AT REITBROOK, GERMANY

Normal faults are due to increase of distance above the dome which in turn is caused by upwarping. (After Behrmann, 1949, p. 201)

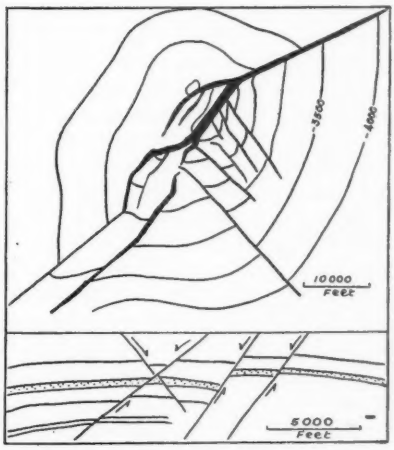

FIGURE 6.—SCHEMATIC MAP OF VAN DOME, VAN ZANDT COUNTY, TEXAS

After Nevin (1949, p. 105). One large normal fault cuts across entire uplift, and radial faults meet in the center. Displacements increase with depth.

A study of such "fracture anomalies" would be comparable to a study of magnetic anomalies. Both anomalies are superimposed on regional patterns: the earth's magnetic field and the trends of regional fractures.

Areas above domes and uplifts are the home of normal or gravity faults. Figure 5 is a cross section above the Reitbrook dome in Germany. At higher levels where the effect of the rising dome is felt less, the faults are smaller; fractures have only begun to form.

Figure 6 is a map and profile across the Van dome in Van Zandt County, Texas, which is one of the most beautiful domes with radial faults above a rising dome. The description of the dome by R. A. Liddle (1936) shows in a number of structure contour maps how the throw of the major faults increases with depth and age. Salt has not been encountered, but the doming is probably caused by a deep salt plug. The profile is in principle very similar to the one shown in Figure 5.

Salt domes are easily imitated, by pushing a plug upward into clay. Such an experiment contributes nothing to the problem of salt intrusion or to the cause of its rise, but it results in very revealing fracture patterns.

Figure 1 of Plate 5 is the surface of a clay model below which a dome has been pushed upward. Water about a tenth of an inch deep is kept on the surface by a low rim around the area of the picture. The upward movement has barely begun, but radial fractures have opened already. These are vertical tension joints which grow more numerous and open wider with increased uplift.

Figure 2 of Plate 5 is the same area but without the water. Radial faults dip about 60°. The model resembles the Van dome in many respects.

The displacement seen in Figure 2 of Plate 5 is about a tenth of an inch. The model in Figure 2 of Plate 5 is 2 inches wide or about $\frac{1}{50,000}$ of a salt dome, which is 1½ miles in diameter. A displacement of a tenth of an inch on the model corresponds to a fault in nature of a displacement of $\frac{50,000}{10}$ of an inch or 5000 inches—about 400 to 500 feet. In the model the faults are exaggerated because they cannot be seen as early as they form, as visibility depends on relief. In nature faults of 10 feet or less of displacement are detectable in the presence of key beds.

Figure 3 of Plate 5 is a later stage of the same experiment. The faults are more pronounced and more numerous, and the area affected is well marked. The displacements have grown to the equivalent of several hundred feet in nature.

It would seem most probable that above rising salt domes such faults and joints could be seen in the field and that a study of their pattern may be a rather easy way of detecting areas of rising domes. This would call for detailed field work and plotting of even the insignificant-looking small faults on large-scale maps or aerial photographs.

Figure 7 is a map showing a fictitious pattern of joints and small faults in an area of rising domes as it might look today. A report on the map may well read as follows:

"A regional pattern dominates the entire area and trends northeast and northwest. The joints are largely vertical and have been plotted where exposures are particularly good, as north of the village of Council Bluff along Fellows Run and the G. S. and A. railroad. This regional pattern has been emphasized by longer lines in Figure 7.

"In some of the exposures along Paper River and its small tributaries in the vicinity of Mt. Agnes other joints appear, and if these are extended they point toward Mt. Agnes and seem to indicate radial tensions joints, but a few radial faults have also been found. There is little doubt that a careful investigation of the Mt. Agnes area will show a rising dome at some depth.

"Another area which may well be worth some study is Mason Hill, south of Henrytown. The picture is not so simple, but there are some diverging joint directions southeast of the Hill and two normal faults to the northwest. Not too much can be said as yet about that area, but it may also be worth investigating. An elongated dome may be found south of Henrytown. I should like to emphasize that a study of the area must include systematic and maybe statistical analyses of all large or small fractures.

"Exposures are not very good, but many small outcrops have been located along streams, roads, or railroad cuts. All the fractures shown on the map have been observed in unconsolidated sand and clays of the Grant Ferry formation."

There is no reason why salt domes should have stopped rising; they may still rise today, and the fracture patterns may well indicate their present movements, even outline their size and shape. If joints and faults form in clay models or sand, there is little reason to assume that they are absent in the field, especially in regions which are covered principally by clay and sand.

Southern California Structures

General remarks.—When it comes to applying the experience gained in a table-sized experi-

ment to the interpretation of cubic miles of nature, the personality of the experimenter enters as an important human factor. One may be cautious, but the other may take off on the wings of his imagination and interpret his findings on the scale of the geologic map of North America or any other sheet that fits his drawing table and suits his fancy.

Up to this point I have been rather cautious, but the occasion calls for a change of heart—even if it be temporary. I will follow in the footsteps of an eminent and well-liked geologist who, as he recently said, "timitly" stuck his neck out in an interpretation of the San Andreas and Garlock fault system. His subject seems particularly appropriate because it deals with a well-known and alive fracture pattern which is more native to California than any native Californian could be.

It would be impossible to discuss the many and varied fractures of Southern California and their relations to the folds, but I can at least point out some rather intriguing problems and show how it may be possible to approach them experimentally.

Out of the many possibilities, I have picked two: the Kettleman Hills and the San Andreas-Garlock fault system (Fig. 8).

Fractures in anticlines.—The north dome of the Kettleman Hills is one of the most beautiful and best-known anticlinal domes. The monumental paper by Woodring, Stewart, and Richards (1940) provides a wealth of valuable information and is most suggestive for experimental imitation.

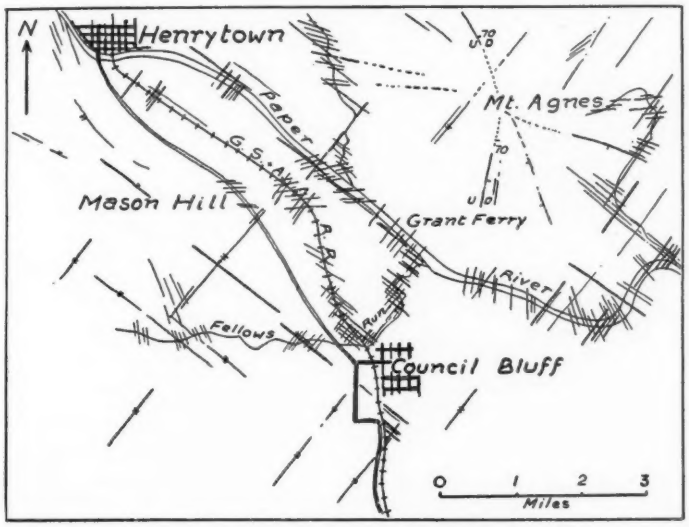

FIGURE 7.—FICTITIOUS MAP OF HENRYTOWN AREA

Showing regional fracture pattern of northwest- and northeast-trending fractures on which locally two patterns have been superimposed indicating fractures which radiate outward from a center.

As the authors see it, the situation is essentially as shown in Figure 9: longitudinal strike faults dip toward the crest of the dome and even include a small graben structure. At the plunging ends the strike faults spread apart. The average dip of the faults is near 60°, which is the same angle that we have met before.

Normal faults at the two plunging ends cut across the anticlinal axis and also dip about 60°.

The authors visualize the deformation of the domes as follows:

"The deformation of the Kettleman Hills is attributed to compression in a north-south direction applied to a northwest-trending zone of weak strata in which en echelon anticlines were being formed. The upward squeezing of incompetent material lifted and folded the strata. . . . The strike faults . . . were evidently formed after the strata had been

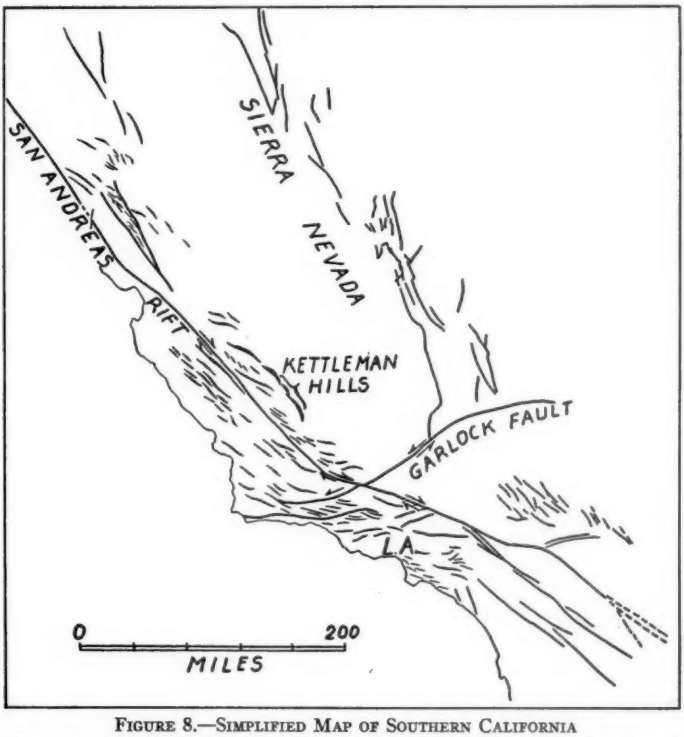

FIGURE 8.—SIMPLIFIED MAP OF SOUTHERN CALIFORNIA

Showing the major rifts, Kettleman Hills area, and tectonic situation which has been imitiated experimentally.

lifted above the level of direct influence of the north-south compression. . . . The diagonal faults appear to have formed before the strata had been raised entirely above the levels of the effect of the north-south compression. The oblique striae of the diagonal faults appear to have been formed in a stage intermediate between the formation of the diagonal and strike faults." (Woodring *et al.*, 1940, p. 152).

An experiment that would imitate the situation should include essentially the following three items:

(1) An elongate dome 18 miles long and 5 miles wide which has risen about 3000 feet should be cut by normal strike faults with slickensides down the dip. The dip should vary

PLATE 5.—FRACTURES ABOVE DOME

FIGURE 1.—Surface of clay model below which a dome has risen about $\frac{1}{10}$ inch. Water covers the surface, and radial tension joints have opened.

FIGURE 2.—Dry surface of clay model above a rising dome. Fractures are normal faults dipping about 60° and radiating outward from center.

FIGURE 3.—Same experiment as in Figure 2 at a later stage. Note slickensides on faults.

PLATE 6.—MODEL OF KETTLEMAN HILLS

FIGURE 1.—Surface of model of North dome of Kettleman Hills. Longitudinal faults dip toward the crest of the anticline and spread apart at the northwest end.

FIGURE 2.—More advanced stage at enlarged scale showing detail of Figure 1, particularly slickensiding down dip.

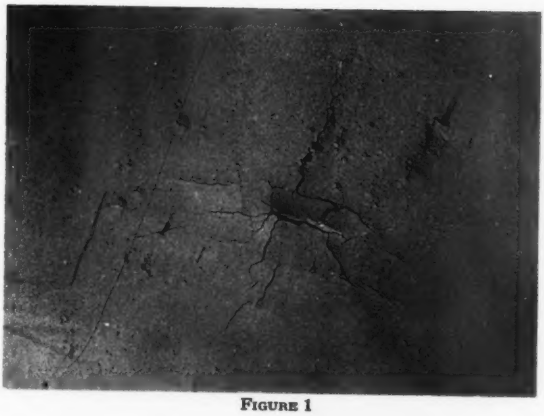

FIGURE 1

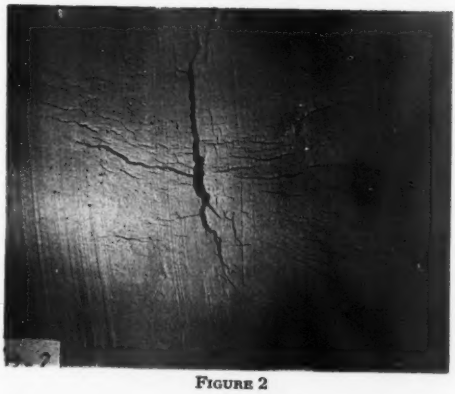

FIGURE 2

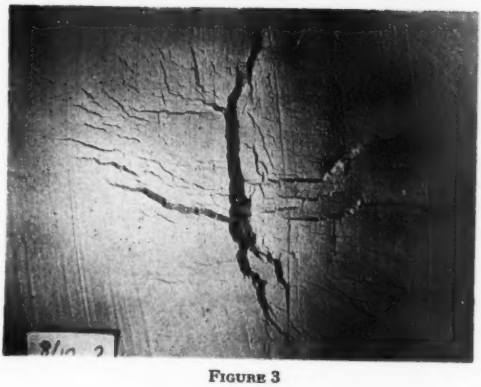

FIGURE 3

FRACTURES ABOVE DOME

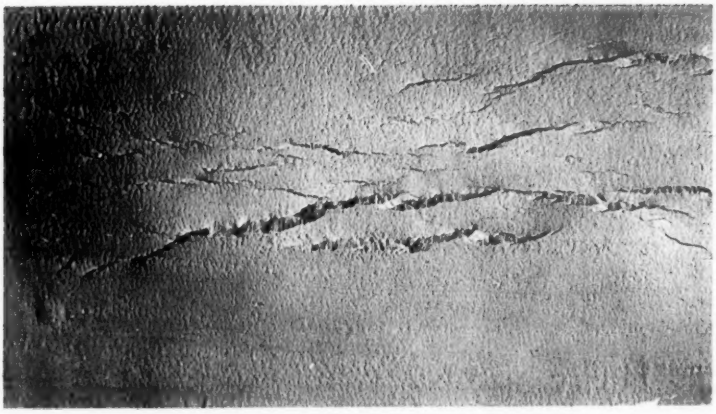

FIGURE 1

FIGURE 2

MODEL OF KETTLEMAN HILLS

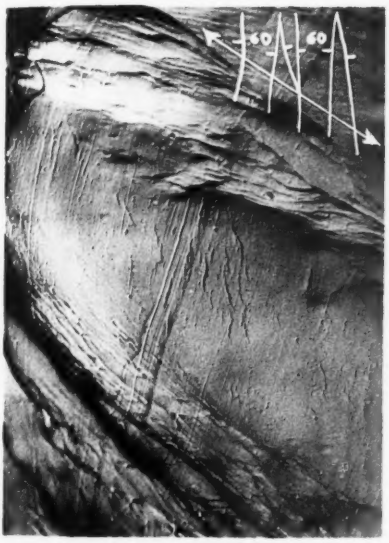

FIGURE 1

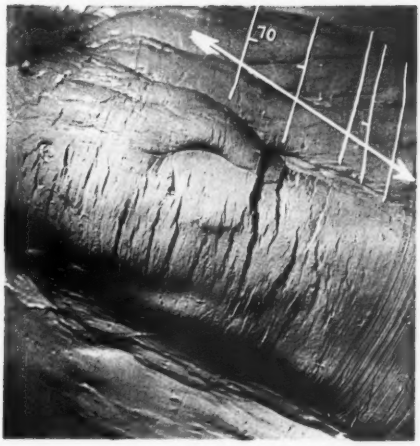

FIGURE 2

FIGURE 3

FIGURE 4

MODEL OF KETTLEMAN HILLS

FIGURE 1

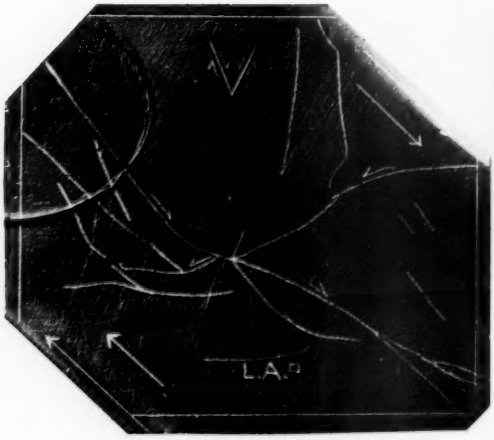

FIGURE 2

FIGURE 3

MODEL OF SOUTHERN CALIFORNIA FRACTURE PATTERN

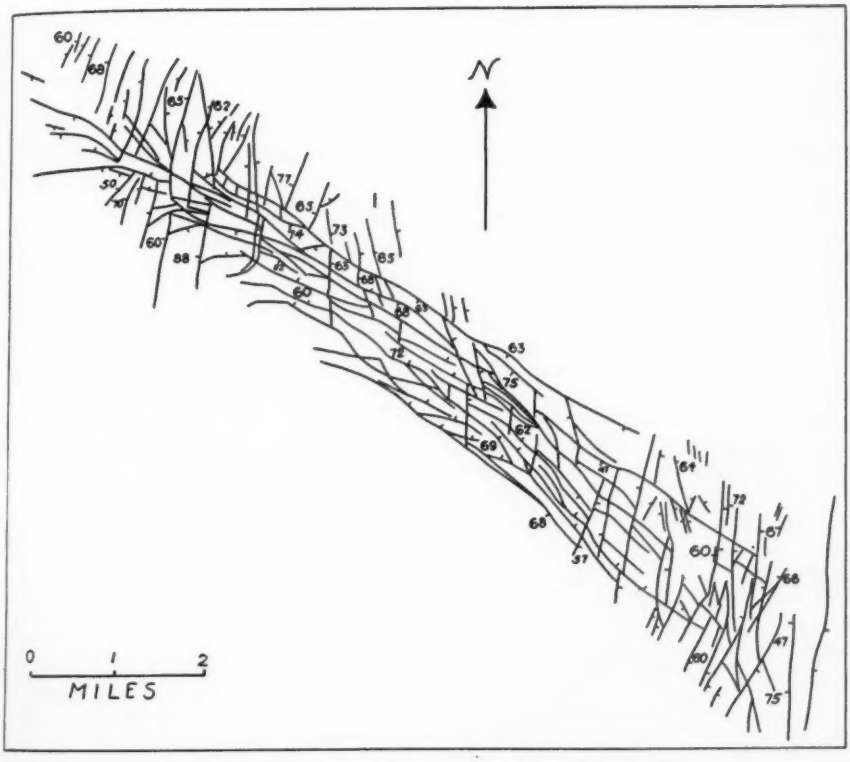

FIGURE 9.—SIMPLIFIED MAP OF KETTLEMAN HILLS, NORTH DOME

Longitudinal normal faults dip toward the central axis of the dome. Diagonal and cross faults at the two plunging ends of the dome are also normal faults. The average dip of all faults is near 60°.

PLATE 7.—MODEL OF KETTLEMAN HILLS

FIGURE 1.—Surface of model of North Dome. Diagonal normal faults at northwest end of anticline dip about 60°.

FIGURE 2.—East end of North Dome and normal faults almost across dome axis. The average dip is also about 60°.

FIGURE 3.—Vertical view of clay model showing north-south movement against a weak zone at an angle of 45°. En echelon folds arise at a 30-degree angle.

FIGURE 4.—Nonrotational deformation pattern and superimposed fault pattern of Southern California for comparison.

PLATE 8.—MODEL OF SOUTHERN CALIFORNIA FRACTURE PATTERN

FIGURE 1.—Clockwise rotational deformation pattern with superimposed faults.

FIGURE 2.—Early experimental pattern at angle between shear planes of 60° does not resemble fault pattern. In order to fit the mapped pattern considerable enlargement of angle is necessary.

FIGURE 3.—Southern California model based on the existence of three deeper crustal blocks as suggested by Ralph Reed. A northwest trend is converted to an east-west trend where an east-west trough meets the northwest-trending block. Faults accompany the folds.

somewhat on the two limbs, and the throw should be up to 300 feet.

(2) Diagonal normal faults should occur where the axis begins to plunge 6°–7° NW. and SE. These faults should be normal faults also, and their displacement should be less than 100 feet. Slickensides should be oblique to the strike and dip.

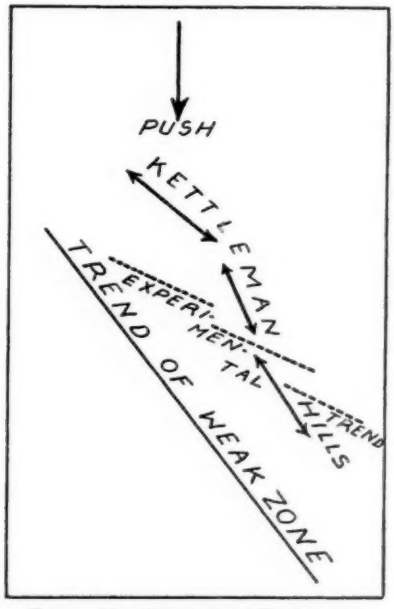

FIGURE 10.—COMPARISON: EXPERIMENT AND KETTLEMAN HILLS

Comparison between trend of en echelon folds caused by a movement at an angle of 45° against a weak zone and buttress beyond and the Kettleman Hills trend.

(3) The dome should be one of a group of three resulting from north-south pressure on a zone of weak strata which trend at an angle of about 45° to the pressure.

In order to keep the experiment simple, I tried to produce each one of these structures singly. The scale was kept at about 1:50,000.

The first group—strike normal faults with striae down dip—was easy to obtain. Strike faults appear in a dome above vertical uplift where competent beds rise by lateral pressure. Figure 1 of Plate 6 is a birdseye view of the dome. The faults dip toward the crest and are well striated. Their strikes diverge at the left end of the dome. The fractures opened almost at once when deformation was started. The dimensions of the dome were about 18 by 5 cm. The uplift is about ¾ cm, and the fault displacement less than a mm. Again deformation has been carried beyond scale-model proportions, for visibility.

Figure 2 of Plate 6 is a closeup of the faults after deformation had gone beyond that which would have been true to scale. The large fractures are strike faults of a displacement equivalent of a throw of 1000 feet or more. Slickensides cover the surfaces and are down the dip of the plane. The area of this photograph is in the center of the dome shown in Figure 1 of Plate 6.

The second group—diagonal joints at the plunging ends of the dome—are also easily imitated (Pl. 7, fig. 1). It is necessary only to construct a plunging anticline; the normal faults are then the logical consequences of arcuation in the direction of the fold axis. The faults also facilitate the extension of the distance between two points, as all normal faults do. In Figure 1 of Plate 7 a broad warped dome plunges to the northwest. Several faults are visible as dark lines which strike north-south and dip west. The heavy lines running across the dome are trowel marks. Orientations for the Kettleman Hills are shown as white lines in the upper right-hand corner.

In the eastern-plunging end of North Dome transverse normal faults appear also, but their angle with the fold axis in the map is near 90° and not about 60° as in the west end.

Figure 2 of Plate 7 shows the imitation of the east end of north dome and faults which are transverse to the dome axis. Normal faults dip about 60° and cut across the dome axis at a large angle. The insert in the northeast corner shows the axis of the dome and the trend of the faults as they are shown in the published map. Striae are oblique but obscure.

The difference in the two setups was produced by a change in plunge and a slight divergence in the direction of the motion.

All structures imitated experimentally so far —longitudinal and transverse faults—can as well be obtained by vertical updoming alone, which may or may not be indirectly due to a

lateral compression as visualized by Woodring, Stewart, and Richards. The experiments demonstrate that the faults are related to the dome and not necessarily diagnostic for a north-south compression.

The third requirement—three en echelon domes of the trend of the Kettleman Hills due to north-south movement at an angle of 45° to a weak zone—is much more difficult, if not impossible, to obtain.

If a weak zone is arranged as called for by the authors, en echelon domes may appear, but not at the trend of the Kettleman Hills. The discrepancy is illustrated in Figure 10.

A weak zone was prepared by placing soft clay between two areas of stiff clay. When the zone which trends northwest was compressed by movement from the north or at 45°, folds appeared in the weak zone, and their axes were at angles of 25°–30° to the trend of the zone and at angles of 60°–70° to the north-south component. One of many experiments which attempted the solution of the problem is shown in Figure 3 of Plate 7. The en echelon domes are not connected and do not trend almost north-south.

The angle between the zone and the movement was then varied from 10° to 60° at 10-degree intervals in six experiments, but in no case did folds appear whose trend paralleled that of the axes of the Kettleman Hills.

This impasse leads me to conclude that another mechanism has been effective. I suggest that the Kettleman Hills are not en echelon structures but one fold which may have followed the original trend of the postulated zone of weakness. It may also be that the movement was not north-south but northeast-southwest. Another possibility would be the action of blocks in the basement which have moved along northeast-trending faults which are responsible for the offset of axial trends between the domes. Northeast-trending faults are in keeping with a north-south movement. Unfortunately, I was unable to imitate the trend of the Hills with any setup in which the movement was north-south. They can be imitated if the component is northeast-southwest and if they are thought of as individual domes which alternate.

San Andreas and Garlock faults.—One of the most intriguing fracture patterns for experimental study is that of the Californian faults. Hill and Dibblee (1953) have contributed a most interesting analysis of the faulting mechanism of that pattern. I was unable to resist the temptation provided by the unusual combination of circumstances and have tried to imitate and analyze the fracture pattern experimentally.

The geological situation as outlined by Hill and Dibblee is shown in Figure 11: the San Andreas fault zone and parallel structures are the right lateral or left shear plane, and the Garlock-Pine Mountain direction the left lateral or right shear plane of one fracture pattern which embraces a rather large area. Assuming that all the points raised as to age, amounts of displacement, and so on are established facts, the problem would be rather simple. A deformational setup will have to be found which results in a fracture pattern of Figure 11. If the fractures are old seams, the Coast Range folds would also have to be explained by the same stress pattern.

The authors state the possibilities as follows: (Hill and Dibblee, 1953, p. 456–457):

> "Thus assuming compressive stresses, the possible effective orientations (Fig. 7) are north-south oppositional forces, or a northeast-southwest counter clockwise couple, or a northwest-southeast clockwise couple. The northeast-southwest counter clockwise couple is favored because this orientation could perhaps more logically cause both the prominent northwest-trending folds of the Coast Ranges and the east-west folds and reverse faults of the transverse Ranges (by upward relief in combination with the north-south shortening of the major shear pattern)."

In an attempt to imitate the fracture pattern the authors' suggestions were followed, and three experiments were set up and several runs made for each setup. The three possibilities are shown in Figure 11. In terms of the fundamental experiments outlined at the beginning, the setup would demand either counter clockwise rotation, clockwise rotation, or a nonrotational setup.

A nonrotational setup is shown in Figure 4 of Plate 7 where the fractures are superimposed on a photograph of the experiment. After considerable internal rotation the two shear planes of the experiment coincide tolerably well with the fractures on Hill and Dibblee's map. The

San Andreas rift is the left shear plane, the Garlock-Pine Mountain fault is the right shear plane, and the relative displacements on these faults and shear planes coincide. The setup might have been nonrotational, and the movement north-south.

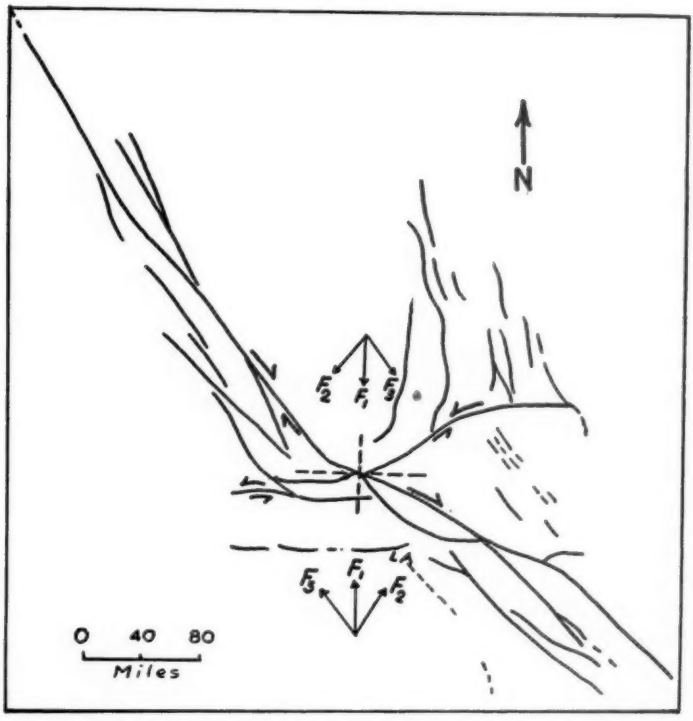

FIGURE 11.—SOUTHERN CALIFORNIA FRACTURE PATTERNS
After Hill and Dibblee. F_1, F_2, F_3, directions of stress which may be the cause of pattern.

A second setup provided external rotation as shown in Figure 1 of Plate 8 where the fracture pattern has also been superimposed on the photograph. The couple coincides with direction F_3 almost parallel with the San Andreas rift.

A third setup would be the mirror image to Figure 1 of Plate 8 and the clockwise rotation.

In all three setups the longest axis of extension is as shown by Hill and Dibblee. The two shear planes become horizontal rifts by internal rotation in the first setup and by external rotation in the second.

None of these setups can possibly be fitted to an early experimental stage because at the beginning the angle between shear planes is near 60° or less, but the angle between the two fault directions is 90° or a good deal more. Figure 2 of Plate 8 shows an early stage in which the angle between shear planes is less than 60° and the superimposed fracture pattern does not fit.

The major event between the opening of fractures in the experiment and later stages is rotation of both shear planes. With rotation the angle increases, and the shear planes become rifts. Only after considerable rotation are the angles and displacements large enough to even resemble the natural pattern. I think that rotation must have occurred in Southern California also. Without rotation of shears the angle could not be between 90° and 120° but would have to be near 60°. If the faults did not rotate

they do not belong to one simultaneous fracture pattern.

If the movement was north-south, the rotation would have been "internal," and the rotation of the two shear planes would have to be symmetrical with reference to the north-south axis. This is clearly not the case because the pattern is asymmetrical. Displacements along the San Andreas rift are larger than those on the Garlock-Pine Mountain fault system. Furthermore, the San Andreas fault zone is much longer and more prominent than the Garlock fault system. This asymmetry suggests asymmetrical deformation probably by external rotation.

Was this rotation clockwise or counterclockwise, or—in Hill and Dibblee's illustration—was the couple parallel to the San Andreas fault effective or the one about normal to it?

In the rotational deformation which I outlined at the beginning one shear plane opened at a small angle with the direction of movement, and the other at a large angle to it. The first one can keep moving as long as the couple is active, but the direction which crosses it owes its displacements only to the rotation of the shear planes and is directly limited by the amount of rotation. True to scale the displacement along the Garlock fault cannot be more than about 1500 feet if the angle between the shear planes opens from 60° to about 90° and the scale is taken to be 1:50,000. On the other hand, there is no limit to the displacements in the direction of the couple.

Since the displacement along the San Andreas rift seems to be very much larger than that along the Garlock fault, I think that the deformation might be clockwise by a couple whose directions would roughly parallel the San Andreas rift, or choice F_3 in Hill and Dibblee's system.

Folds appear in the direction which bisects the smaller angle in any system, or parallel to the transverse range. This position would hold in all three possibilities because the direction of maximum shortening is normal to it—namely, north-south.

Consider for a moment what might happen if the faults did not rotate. The wedges would migrate toward each other and would have to pile up in a system of folds and oblique thrusts. This does not seem to have happened at the scale which would be proportional to the displacements that have been suggested for the San Andreas rift.

These attempts to obtain, by any of these experiments, a system of faults that intersect at a wide angle seem to suffer from over-simplification in the basic assumption or in the scale of the model. At any rate, another experiment was tried combining Ralph Reed's (1933) suggestion of the existence of three blocks in combination with Hill and Dibblee's analysis of the simultaneous fracture pattern.

The blocks were arranged as shown in Reed's maps, moving generally from north to south. The result is shown in Figure 3 of Plate 8. The individual blocks are strongly effective, producing two fault systems, trending northwest and northeast. Folds accompany the northwest system, grade into an east-west trend, but then continue to the southeast. The fracture pattern and Hill and Dibblee's arrows have been superimposed. Even the Kettleman Hills have put in an appearance (K). The arrow at the top indicates the experimental movement. This experiment seems to have come a little closer to the observed pattern.

It would seem to me that the analysis by Hill and Dibblee is perhaps a bit too general and that we may have to include movements of larger crustal blocks which partly influence and guide the fracture patterns. If only one pattern is assumed, considerable asymmetrical clockwise external rotation seems inevitable.

Conclusion

have now arrived at the farthest end of the proverbial limb and also at the end of my time. It is impossible to outline more examples, even though I feel tempted to present to you such easily imitated structures as subsiding cauldrons and ring dikes or reversed faults and overthrusts in Appalachian folds. All fracture patterns can be analyzed by reducing them to the first four experiments. One natural pattern may well be larger than the deformation plan which could represent it. It is therefore most important to establish the size of a homogeneously deformed area and not to exceed it. The Kettleman Hills are of the proper order for one experiment, but the California fracture system may

include too large an area. It is probably a composite picture of smaller areas, each deformed somewhat differently, as suggested in the last experiment.

I have presented little that is really new. Experiments have been made ever since the first geologist wrinkled his wife's tablecloth to demonstrate folding. Many kinds of experiments have been described and many kinds of materials have been used. It is obvious that as a whole the experimenter and his audience were rather discouraged and maybe often disgusted.

The reason for the discouraging results lies first in the lack of proper scale-model proportions. If the experiment is out of scale, the result is not like the object which the experimenter admired, and reasonably enough he returns to nature and to interpretation by intuition.

Secondly, most experiments did not result in structural patterns but in individual structures, as for instance a fracture or a fold. The mutual relationship between folds and fractures, domes and fractures or folds, cleavage and fractures, is much more stimulating than one structure by itself removed from its environment.

In my opinion, every geologist should have some experience in experimentation. Many interpretations would never have been published if the author had only once tried his suggested mechanism of folding or faulting in an experiment.

The occupation with fracture patterns and various and sundry mechanical principles has a sobering effect on the one hand and is most stimulating on the other.

I assure you that I have learned a great deal by experimenting and I am certain that all those who have tried have also profited by the experience.

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BIBLIOGRAPHY AND INDEX OF LITERATURE ON URANIUM AND THORIUM AND RADIOACTIVE OCCURRENCES IN THE UNITED STATES

PART 4: ARKANSAS, IOWA, KANSAS, LOUISIANA, MINNESOTA, MISSOURI, NEBRASKA NORTH DAKOTA, OKLAHOMA, SOUTH DAKOTA AND TEXAS

BY MARGARET COOPER

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FOREWORD

The following bibliography consists of references to published literature, press releases, speeches, and both open-file and other unclassified reports dealing with uranium, thorium, and radioactive occurrences in Arkansas, Iowa, Kansas, Louisiana, Minnesota, Missouri, Nebraska, North Dakota, Oklahoma, South Dakota, and Texas. It is Part 4 of a comprehensive bibliography planned to cover references to all similar deposits throughout the world. While the object has been to make the present bibliography as all-inclusive as possible, from the point of view of including all the major papers and at least one reference to each known radioactive occurrence in these eleven States, only references for which the original text was readily available for examination and checking have been cited at this time. The remaining old and new references will be added to this basic list when the section is ready for inclusion in the comprehensive volumes, planned for future publication as a complete bibliography of the entire United States and world.

The main bibliography consists of an author section, in which each reference has been assigned an individual item number. Following the author listings are the anonymous notes, which are listed in chronological order and alphabetically by title within each year. The bibliography proper is followed by three indexes: Index I, Gazetteer for Arkansas, Iowa, Kansas, Louisiana, Minnesota, Missouri, Nebraska, North Dakota, Oklahoma, South Dakota, and Texas; Index II, Geographical Index for Arkansas, Iowa, Kansas, Louisiana, Minnesota, Missouri, Nebraska, North Dakota, Oklahoma, South Dakota, and Texas; Index III, Subject Index for Arkansas, Iowa, Kansas, Louisiana, Minnesota, Missouri, Nebraska, North Dakota, Oklahoma, South Dakota, and Texas. The geographical and subject indexes have been made as detailed as practicable since the main reference entries have not been annotated. Where there are variations in spelling or alternate names for the same locality, a standard form has been used in the geographical and subject indexes, and the variations have been noted in the gazetteer. Where county boundary lines have been changed since a reference was written, the locality has been listed under the county in which it is found today.

A fairly extensive survey has been made of

the geological and mining literature published through 1949 in compiling the references included in this bibliography. A few of the standard American and English geological and mining publications have also been reviewed up to the early part of 1952. Every reference cited in the bibliography has been checked with the original text. References re-cited from the first three sections of the bibliography,* Part 1 covering Arizona, Nevada, and New Mexico, Part 2 covering California, Idaho, Montana, Oregon, Washington, and Wyoming, and Part 3 covering Colorado and Utah, have been assigned the same item number as in Parts 1, 2, and 3. The authors and item numbers of these re-cited references have also been recorded here in regular alphabetical order in the second group of author listings, which gives all the new references on the States covered by this bibliography.

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Safford No. 7 well in Douglas (?) formation: showed field radioactivity of 5 on 0.2 scale, and precipitates collected from pipes showed 0.008% eU_3O_8 and 0.000% U_3O_8: 582.

Scully well of Cities Service Oil Co. in Kansas City and Arbuckle formations: Serial No. 16302, showed field radioactivity of 10 on 0.2 scale; no U_3O_8 reported in precipitates or brines: 582; Serial No. 15633, showed field radioactivity of 20 on 0.2 scale; no U_3O_8 reported in precipitates or brines: 582.

Scully well of Sinclair Oil Co. in Arbuckle formation: Serial No. 15608, showed field radioactivity of 40 on 0.2 scale; no U_3O_8 reported in precipitates or brines: 582.

Scully well of Sinclair Oil Co. in Kansas City and Arbuckle formations: Serial No. 15552, showed field radioactivity of 50 on 0.2 scale, and precipitates collected from pipes showed 0.28% eU_3O_8 and 0.000% U_3O_8: 582.

Scully No. 1 well of Sinclair Oil Co. in Arbuckle formation: showed field radioactivity of 2 on 0.2 scale, and precipitates collected from pipes showed 1.34% eU_3O_8 and 0.003% U_3O_8: 582.

Scully No. 2 well of Sinclair Oil Co. in Arbuckle formation: showed field radioactivity of 2 on 0.2 scale, and precipitates collected from pipes showed 0.38% eU_3O_8 and 0.000% U_3O_8: 582.

Scully No. 3 well of Sinclair Oil Co. in Arbuckle formation: showed field radioactivity of 3 on 0.2 scale and precipitates collected from pipes showed 0.15% eU_3O_8 and 0.000% U_3O_8: 582.

Scully No. 4 well of Cities Service Oil Co. in Arbuckle formation: showed field radioactivity of 5 on 0.2 scale, and precipitates collected from pipes showed 0.42% eU_3O_8 and 0.001% U_3O_8: 582.

Scully No. 6 well of Sinclair Oil Co. in Arbuckle formation: showed field radioactivity of 5 on 0.2 scale, and precipitates collected from pipes showed 0.61% eU_3O_8 and 0.000% U_3O_8: 582.

Scully No. 9 well of Cities Service Oil Co. in Arbuckle formation: showed field radioactivity of 3 on 0.2 scale; no samples: 582.

Scully No. 15 well of Sinclair Oil Co. in Arbuckle formation: showed field radioactivity of 3 on 0.2 scale; no U_3O_8 reported in precipitates or brines: 582.

Scully No. 16 well of Sinclair Oil Co.: precipitates collected from pipes or tanks showed 0.025% eU_3O_8 and 0.001% U_3O_8: 582.

Scully No. 25 well of Sinclair Oil Co. in Arbuckle formation: showed field radioactivity of 10 on 0.2 scale and precipitates contaminated with surface debris showed 0.075% eU_3O_8 and 0.000% U_3O_8: 582.

Scully No. 29 well of Sinclair Oil Co. in Arbuckle formation: showed field radioactivity of 2 on 0.2 scale; no U_3O_8 reported in precipitates or brines: 582.

Skaer well of Sinclair-Cities Service Oil Cos. in Kansas City, Simpson, and Arbuckle formations: showed field radioactivity of 7 on 0.2 scale; no U_3O_8 reported in precipitates or brines: 582.

Skaer No. 6 well of Sinclair-Cities Service Oil Cos. in Kansas City formation: precipitates contaminated with surface debris showed 0.044% eU_3O_8 and 0.000% U_3O_8: 582.

Skaer No. 14 well of Sinclair-Cities Service Oil Cos. in Arbuckle formation, plugged back to Kansas City formation: showed field radioactivity of 2 on 0.2 scale; no samples: 582.

Skaer No. 16 well of Sinclair-Cities Service Oil Cos. in Arbuckle formation, plugged back to Kansas City formation: showed field radioactivity of 10 on 0.2 scale, and precipitates collected from pipes showed 0.17% eU_3O_8 and 0.000% U_3O_8: 582.

Skaer No. 19 well of Sinclair-Cities Service Oil Cos. in Simpson formation: showed field radioactivity of 3 on 0.2 scale; no samples: 582.

Smith well of Cities Service Oil Co. in Kansas City and Arbuckle formations: Serial No. 16305, showed field radioactivity of 10 on 0.2 scale, and precipitates contaminated with surface debris showed 0.093% eU_3O_8 and 0.001% U_3O_8: 582; Serial No. 16313, showed field radioactivity of 20 on 0.2 scale, and precipitates contaminated with surface debris showed 0.021% eU_3O_8 and 0.000% U_3O_8: 582.

Smith No. 20 well of Cities Service Oil Co.: precipitates collected from pipes or tanks showed 0.085% eU_3O_8 and 0.000% U_3O_8: 582.

Smith No. 25 well of Cities Service Oil Co. in Arbuckle formation: showed field radioactivity of 50 on 0.2 scale, and precipitates collected from pipes showed 0.58% eU_3O_8 and 0.000% U_3O_8: 582.

Smith No. 31 well of Cities Service Oil Co. in Arbuckle formation: showed field radioactivity of 5 on 0.2 scale, and precipitates collected from pipes showed 0.28% eU_3O_8 and 0.000% U_3O_8: 582.

South Anderson well: precipitates contaminated with surface debris showed 0.011% eU_3O_8 and 0.000% U_3O_8: 582.

South Anderson No. 2 well: precipitates collected from pipes or tanks showed 0.31% eU_3O_8 and 0.000% U_3O_8: 582.

South Anderson No. 6 well: precipitates

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collected from pipes or tanks showed 0.38% eU_3O_8 and 0.000% U_3O_8: 582.
South Anderson No. 7 well: precipitates contaminated with surface debris showed 0.007% eU_3O_8 and 0.000% U_3O_8: 582.
Starkey well of Sinclair-Cities Service Oil Cos. in Kansas City, Simpson, and Arbuckle formations: showed field radioactivity of 5 on 0.2 scale, and precipitates contaminated with surface debris showed 0.046% eU_3O_8 and 0.002% U_3O_8: 582.
Starkey No. 2 well of Sinclair-Cities Service Oil Cos. in Arbuckle formation: precipitates collected from pipes and tanks showed 0.003% eU_3O_8 and 0.000% U_3O_8: 582.
Starkey No. 4 well of Sinclair-Cities Service Oil Cos. in Kansas City formation: showed no field radioactivity but precipitates collected from pipes showed 0.001% eU_3O_8 and 0.000% U_3O_8: 582.
Starkey No. 14 well of Sinclair-Cities Service Oil Cos.: precipitates contaminated with surface debris showed 0.049% eU_3O_8 and 0.000% U_3O_8: 582.
Suits well: reports on two samples, Serial Nos. 15541–15542: precipitates collected from pipes or tanks showed 0.16% and 0.22% eU_3O_8 and 0.000% U_3O_8: 582.
Suits (?) well: Serial No. 15607, brines showed 0.1 mg. U_3O_8/liter: 582.
Suits well of Hammer and Maclean Drilling Co.: showed field radioactivity of 10 on 0.2 scale; no reported U_3O_8 in precipitates or brines: 582.
Suits well of Magnolia Petroleum Co.: reports of two samples, Serial Nos. 15536–15537: precipitates collected from pipes or tanks showed 0.056% and 0.049% eU_3O_8 and 0.002% and 0.001% U_3O_8: 582.
Suits well of Magnolia Petroleum Co. in Douglas and Kansas City formations: showed field radioactivity of 5 on 0.2 scale, and precipitates collected from pipes showed 0.002% eU_3O_8 and 0.000% U_3O_8: 582.
Suits No. 1 well of Magnolia Petroleum Co. in Kansas City formation: showed field radioactivity of 2 on 0.2 scale, and brines showed 0.1 mg. U_3O_8/liter: 582.
Suits No. 1½ well of Magnolia Petroleum Co. in Douglas formation: showed field radioactivity of 3 on 0.2 scale, and precipitates collected from pipes showed 0.34% and 0.67% eU_3O_8 and 0.000% and 0.001% U_3O_8: 582.
Suits No. 3 well of Magnolia Petroleum Co. in Arbuckle formation, plugged back to Kansas City formation: showed field radioactivity of 2 on 0.2 scale; no U_3O_8 reported in precipitates or brines: 582.
Suits No. 7 well of Magnolia Petroleum Co. in Simpson formation: showed field radioactivity of 2 on 0.2 scale, and precipitates collected from pipes showed 1.31% and 0.000% eU_3O_8 and 0.003% and 0.001% U_3O_8: 582.
Unnamed well of Cities Service Oil Co.: precipitates collected from pipes or tanks showed 0.001% eU_3O_8 and 0.000% U_3O_8: 582.
Unnamed well of Pure Oil Co.: showed field radioactivity of 5 on 0.2 scale; no samples: 582.
Unnamed well of United Oil Co. in Douglas formation: showed field radioactivity of 15 on 0.2 scale; a gas well, so radioactivity may be caused by radon; no samples: 582.
Unnamed wells (two) of United Oil Co: one sample from each: precipitates collected from pipes or tanks showed 0.16% eU_3O_8 and 0.000% U_3O_8; precipitates contaminated with surface debris showed 0.002% eU_3O_8 and 0.000% U_3O_8: 582.
Varner well of Cities Service Oil Co. in Kansas City and Arbuckle formations: showed field radioactivity of 10 on 0.2 scale, and brines showed 0.14 mg. U_3O_8/liter: 582.
Varner No. 13 well of Cities Service Oil Co. in Arbuckle formation: showed field radioactivity of 15 on 0.2 scale; no samples: 582.
Varner No. 19 well of Cities Service Oil Co. in Arbuckle formation: showed field radioactivity of 15 on 0.2 scale, and precipitates collected from pipes showed 0.064% eU_3O_8 and 0.000% U_3O_8: 582.
Varner No. 26 well of Cities Service Oil Co. in Arbuckle formation: showed field radioactivity of 15 on 0.2 scale; no samples: 582.
Wallace well of Cities Service Oil Co. in Kansas City and Arbuckle formations: showed field radioactivity of 35 on 0.2 scale; no U_3O_8 reported in precipitates or brines: 582.
Wallace No. 4 well of Cities Service Oil Co. in Arbuckle formation: showed field radioactivity of 3 on 0.2 scale, and precipitates collected from pipes showed 0.17% eU_3O_8 and 0.000% U_3O_8: 582.
Beadles well in Arbuckle formation: precipitates contaminated with surface debris showed 0.002% eU_3O_8 and 0.001% U_3O_8: 582.
Bush well of Morrison Oil Co. in Arbuckle formation: reports on two samples: precipitates collected from pipes or tanks showed 0.12% eU_3O_8 and 0.000% U_3O_8; brines showed 0.09 mg. U_3O_8/liter: 582.
Darter (?) well: precipitates collected from pipes or tanks showed 0.21% eU_3O_8 and 0.001% U_3O_8: 582.
Hawk well in Kansas City and Hunton formations: precipitates contaminated with surface debris showed 0.001% eU_3O_8 and 0.002% U_3O_8: 582.
Klinger well in Kansas City formation: brines showed 0.04 mg. U_3O_8/liter: 582.
Klinger No. 1 well in Simpson formation:

precipitates collected from pipes or tanks showed 0.070% eU_3O_8 and 0.000% U_3O_8: 582.
Liggett No. 6 well of Sohio Petroleum Co. in Cherokee (Bartlesville) formation: precipitates collected from pipes or tanks showed 0.002% eU_3O_8 and 0.000% U_3O_8: 582.
Liggett No. S-1 well of Sohio Petroleum Co. in Douglas formation: precipitates collected from pipes or tanks showed 0.001% eU_3O_8 and 0.000% U_3O_8: 582.
McLaughlin No. 1 well in Kansas City formation: precipitates collected from pipes or tanks showed 0.22% eU_3O_8 and 0.001% U_3O_8: 582.
Robinson No. 1 well of Deep Rock Oil Co. in Viola formation: precipitates collected from pipes or tanks showed 1.33% eU_3O_8 and 0.000% U_3O_8: 582.
Starkey well in Arbuckle (?) formation: reports on two samples: precipitates contaminated with surface debris showed 0.004% and 0.085% eU_3O_8 and 0.003% and 0.000% U_3O_8: 582.
Stern No. 1 well in Viola formation: precipitates collected from pipes or tanks showed 0.002% eU_3O_8 and 0.000% U_3O_8: 582.
Young No. 4A well in Mississippian formation: precipitates collected from pipes or tanks showed 0.32% eU_3O_8 and 0.000% U_3O_8: 582.
Radiometric Analyses—
Drill Samples—
Ambler No. 1 well, analysis by Hammer and Maclean Drilling Co.: range in percent eU_3O_8, 0.000–0.005: 582.
Ambler No. 2 well, analysis by Hammer and Maclean Drilling Co.: range in percent eU_3O_8, 0.002–0.006: 582.
Ambler No. 3 well, analysis by Hammer and Maclean Drilling Co.: range in percent eU_3O_8, 0.000–0.005: 582.
Ambler No. 4 well, analysis by Hammer and Maclean Drilling Co.: range in percent eU_3O_8, 0.000–0.004: 582.
Ambler No. 5 well, analysis by Hammer and Maclean Drilling Co.: range in percent eU_3O_8, 0.001–0.003: 582.
Augustine No. 1 well, analysis by Sheldon and Wixon: range in percent eU_3O_8, 0.000–0.001: 582.
Bates No. 2 well, analysis by Hammer and Maclean Drilling Co.: range in percent eU_3O_8, 0.000–0.005: 582.
Foster No. 14 well, analysis by Magnolia Petroleum Co.: range in percent eU_3O_8, 0.000–0.008: 582.
Foster No. 21 well, analysis by Magnolia Petroleum Co.: range in percent eU_3O_8, 0.000–0.005: 582.
Koogler No. 71 well, analysis by Magnolia Petroleum Co.: range in percent eU_3O_8, 0.002–0.004: 582.
Kramer No. 14 well, analysis by Magnolia Petroleum Co.: range in percent eU_3O_8, 0.001–0.006: 582.
Kramer No. 17 well, analysis by Magnolia Petroleum Co.: range in percent eU_3O_8, 0.000–0.005: 582.
Kramer No. 18 well, analysis by Magnolia Petroleum Co.: range in percent eU_3O_8, 0.000–0.006: 582.
Liggett No. W-14 well, analysis by Sohio Petroleum Co.: range in percent eU_3O_8, 0.003–0.004: 582.
Linn No. 1A well, analysis by Colpitt: range in percent eU_3O_8, 0.000–0.004: 582.
Loomis No. 1 well, analysis by Aikman and Bennetts: range in percent eU_3O_8, 0.001–0.006: 582.
Loomis No. 2 well, analysis by Rex and Morris Drilling Co.: range in percent eU_3O_8, 0.000–0.006: 582.
Loomis No. 7 well, analysis by Rex and Morris Drilling Co.: range in percent eU_3O_8, 0.000–0.007: 582.
Loomis No. 10 well, analysis by Cosmic Oil Co.: range in percent eU_3O_8, 0.000–0.002: 582.
Lychlyter (?) well, analysis by Palmer Co.: range in percent eU_3O_8, 0.000–0.006: 582.
Moyle No. 2 well, analysis by Hammer and Maclean Drilling Co.: range in percent eU_3O_8, 0.000–0.005: 582.
Moyle No. 4 well, analysis by Hammer and Maclean Drilling Co.: range in percent eU_3O_8, 0.000–0.006: 582.
Palmer No. 7A well, analysis by Magnolia Petroleum Co.: range in percent eU_3O_8, 0.001–0.006: 582.
Perry No. 1 well, analysis by Aikman and others: range in percent eU_3O_8, 0.001–0.003: 582.
Sanford No. 1 well, analysis by Alter and Brackensiek: range in percent eU_3O_8, 0.000–0.006: 582.
Scully No. 29 well, analysis by Sinclair Oil Co: range in percent eU_3O_8, 0.000–0.004: 582.
Scully No. 120 well, analysis by Cities Service Oil Co.: range in percent eU_3O_8, 0.000–0.004: 582.
South Anderson No. 1 well, analysis by Aikman and Braden: range in percent eU_3O_8, 0.000–0.010: 582.
South Anderson No. 2 well, analysis by Aikman and Braden: range in percent eU_3O_8, 0.000–0.002: 582.
South Anderson No. 7 well, analysis by Magnolia Petroleum Co.: range in percent eU_3O_8, 0.030 (one sample): 582.
South Anderson No. 9 well, analysis by Magnolia Petroleum Co.: range in percent eU_3O_8, 0.000–0.002: 582.
Suits No. 1 well, analysis by Hammer and Maclean Drilling Co.: range in percent eU_3O_8, 0.000–0.002: 582.
Suits No. 9 well, analysis by Magnolia Petroleum Co.: range in percent eU_3O_8, 0.000–0.005: 582.
Taylor No. 1 well, analysis by Adkins Co.: range in percent eU_3O_8, 0.001–0.006: 582.
Thompson No. 1 well, analysis by Palmer

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Co.: range in percent eU_3O_8, 0.000–0.007: 582.
West No. 1 well, analysis by Richmond and Riegle: range in percent eU_3O_8, 0.000–0.007: 582.
Wilson No. 1½ well, analysis by Blakeslee and others: range in percent eU_3O_8, 0.000–0.002: 582.
Uranium Occurrences—
North Augusta oil field in southeast part: radium- and hydrocarbon-bearing Ordovician and Pennsylvanian dolomites and limestones: 426.
Cherokee County
Geophysical Exploration (Ground)—
Geiger-Mueller Counter Surveys—
Tri-State District: traverses made above both mined and unmined areas in the lead-zinc district: 578; radioactivity traverses showed no relation to underlying structure: 578; proved of no value in location of orebodies or delineating major structural features in this area: 578.
Uranium Exploration—
Geophysical Exploration (Ground)—
Tri-State District: Geiger-Mueller Counter Surveys: traverses made above both mined and unmined areas in the lead-zinc district: 578; radioactivity traverses showed no relation to underlying structure: 578; proved of no value in location of ore bodies or delineating major structural features in this area: 578.
Coals, Uranium-bearing
See under individual county names and under Index III, Coals, Uranium-bearing—Kansas: 443.
Cowley County
Radioactive Oil Wells—
Bauman well in Simpson formation: brines showed 0.05 mg. U_3O_8/liter: 582.
Bower well of Continental Oil Co. in Arbuckle and Kansas City formations: reports on four samples: precipitates collected from pipes or tanks showed 0.048%, 5.16%, and 8.15% eU_3O_8 and 0.001%, 0.001%, and 0.000% U_3O_8; precipitates contaminated with surface debris showed 0.32% eU_3O_8 and 0.001% U_3O_8: 582.
Bower or Graham well of Continental Oil Co: precipitates collected from pipes or tanks showed 10.85% eU_3O_8 and 0.001% U_3O_8: 582.
Boyd well in Cherokee (Bartlesville) formation: precipitates contaminated with surface debris showed 0.040% eU_3O_8 and 0.001% U_3O_8: 582.
Dilworth Fee No. 2 well of Dilworth and Miller in Mississippian formation: reports on two samples: precipitates collected from pipes or tanks showed 0.24% and 0.48% eU_3O_8 and 0.005% and 0.002% U_3O_8: 582.
Finch well of Hill Oil Co. in Kansas City and Cherokee (Bartlesville) formations: precipitates contaminated with surface debris showed 0.002% eU_3O_8 and 0.002% U_3O_8: 582.
Lewis well in Arbuckle formation: precipitates collected from pipes or tanks showed 0.001% eU_3O_8 and 0.001% U_3O_8: 582.
Radcliffe well: reports on two samples: precipitates contaminated with surface debris showed 0.001% and 0.019% eU_3O_8 and 0.000% and 0.001% U_3O_8: 582.
Weathered well of Bennett and others in Arbuckle formation: reports of two samples: precipitates contaminated with surface debris showed 0.027% and 0.085% eU_3O_8 and 0.001% and 0.000% U_3O_8: 582.
Radiometric Analyses—
Drill Samples—
Dilworth Fee No. 1 well, analysis by Dilworth and Miller: range in percent eU_3O_8, 0.002–0.003: 582.
Dilworth Fee No. 2 well, analysis by Dilworth and Miller: range in percent eU_3O_8, 0.003: 582.
Crawford County
Radioactive Coal—
Bevier coal in Cherokee formation from abandoned strip pit, slacked: radiometric analysis showed 0.001% eU_3O_8: 582.
Radiometric Analyses—
Coal—
Bevier coal in Cherokee formation from abandoned strip pit, slacked: radiometric analysis showed 0.001% eU_3O_8: 582.
Elk County
Radiometric Analyses—
Drill Samples—
Shipley No. 1 well, analysis by Bird and Hanley: range in percent eU_3O_8, 0.000–0.007: 582.
Franklin County
Radioactive Coal—
Ottawa coal in Douglas formation at an outcrop: radiometric analysis showed 0.001% eU_3O_8: 582.
Radiometric Analyses—
Coal—
Ottawa coal in Douglas formation at an outcrop: radiometric analysis showed 0.001% eU_3O_8: 582.
Geophysical Exploration (Ground)
See under individual county names and under Index III, Geophysical Exploration (Ground)—Kansas: 578.
Limestones, Radium-bearing
See under individual county names and under Index III, Limestones, Radium-bearing—Kansas: 426.
Linn County
Radioactive Asphalt—
Sample from SE corner of county: radiometric analysis showed 0.001% eU_3O_8: 582.
Radiometric Analyses—
Asphalt—
Sample from SE corner of county: radiometric analysis showed 0.001% eU_3O_8: 582.
Marion County
Radioactive Oil Wells—
Bevins No. 4 well in Mississippian formation: precipitates collected from pipes or

tanks showed 0.022% eU_3O_8 and 0.000% U_3O_8: 582.
Greeley well in Viola formation: precipitates collected from pipes or tanks showed 0.013% eU_3O_8 and 0.001% U_3O_8: 582.
Joliffe well of Faylor (?) Co. in Viola formation: precipitates contaminated with surface debris showed 0.048% eU_3O_8 and 0.001% U_3O_8: 582.
Joliffe (?) well: reports on two samples, Serial Nos. 3660 and 18375: precipitates collected from pipes or tanks showed 0.27% eU_3O_8 and 0.001% U_3O_8; precipitates contaminated with surface debris showed 0.083% eU_3O_8 and 0.003% U_3O_8: 582.
Joliffe (?) well (different location): reports on five samples, Serial Nos. 3661, 3663, 5799, 5802, and 5808: precipitates contaminated with surface debris showed 0.023%, 0.059%, 0.103%, 0.20%, and 0.55% eU_3O_8 and no listing, 0.003%, 0.001%, 0.000%, and 0.001% U_3O_8: 582.
Reamy well of the Cooperative Refinery Association in Kansas City and Viola formations: precipitates contaminated with surface debris showed 0.002% eU_3O_8 and 0.001% U_3O_8: 582.
Spier (?) well: precipitates contaminated with surface debris showed 0.088% and 0.10% eU_3O_8 and 0.003% and 0.000% U_3O_8: 582.
Spier No. 1 well of C. R. Colpitt in Mississippian formation: reports on five samples: precipitates collected from pipes or tanks showed 0.92% eU_3O_8 and 0.001% U_3O_8; precipitates contaminated with surface debris showed 0.077%, 0.088%, 0.091%, and 0.63% eU_3O_8 and 0.001%, 0.003%, 0.001%, and 0.000% U_3O_8: 582.
Spier No. 1A well of Berry and Eells: precipitates contaminated with surface debris showed 0.001% eU_3O_8 and no listing for U_3O_8: 582.
Radiometric Analyses—
Drill Samples—
Joliffe No. 1 well, analysis by Berry and Eells Co.: range in percent eU_3O_8 for two sets of samples: 0.001–0.004, and 0.000–0.003; for four other samples from drilling mud, the results were 0.003, 0.004, 0.005, and 0.007 mg. uranium per liter: 582.
Nonken No. 1 well, analysis by Progressive Co.: range in percent eU_3O_8, 0.000–0.008: 582.
Unnamed well, analysis by Fleet Co.: range in percent eU_3O_8, 0.002–0.004: 582.
Wenger No. 1 well: range in percent eU_3O_8, 0.001–0.004: 582.
Origin of Uranium Occurrences
See under individual county names and under Index III, Origin—Uranium Occurrences—Kansas: 582.
Osage County
Radioactive Coal—
Nodaway coal in Wabaunsee formation in strip pit: radiometric analysis showed 0.001% eU_3O_8: 582.
Radiometric Analyses—
Coal—
Nodaway coal in Wabaunsee formation in strip pit: radiometric analysis showed 0.001% eU_3O_8: 582.
Phosphorites, Uranium-bearing
See under individual county names and under Index III, Phosphorites, Uranium-bearing—Kansas: 462.
Radioactive Asphalt
See under individual county names and under Index III, Radioactive Asphalt—Kansas: 582.
Radioactive Coal
See under individual county names and under Index III, Radioactive Coal—Kansas: 582.
Radiometric Analyses—Asphalt, Coal, Drill Samples
See under individual county names and under Index III, Radiometric Analyses—Asphalt, —Coal,—Drill Samples—Kansas: 582.
Sedgwick County
Radiometric Analyses—
Drill Samples—
Keys No. 3 well, analysis by Vickers and Hinkle: range in percent eU_3O_8, 0.000–0.005: 582.
Rimel No. 1 well, analysis by James Co.: range in percent eU_3O_8, 0.000–0.008: 582.
Rimel No. 2 well, analysis by Derby: range in percent eU_3O_8, 0.000–0.007: 582.
Soukup No. 1 well, analysis by Shawver and others: range in percent eU_3O_8, 0.001–0.005: 582.
Trustee No. 8 well, analysis by Fischer and Lauck: range in percent eU_3O_8, 0.000–0.003: 582.
Southeast Part
Radioactive Coal—
Pennsylvanian coals in Bourbon, Crawford, Franklin, and Osage Cos.: radiometric analyses of 15 samples showed radioactivity in only five samples ranging from 0.001–0.004% eU_3O_8: 582.
Radiometric Analyses—
Coal—
Pennsylvanian coal in Bourbon, Crawford, Franklin, and Osage Cos.: radiometric analyses of fifteen samples showed radioactivity in only five samples ranging from 0.001–0.004% eU_3O_8: 582.
Uranium Occurrences—
Oil and Gas fields: uranium believed to be present in greater-than-normal amounts in subsurface rocks because of abnormally high concentrations of radium in precipitates and drill samples, concentration of radium in comparatively small areas, and presence of helium, probably of radiogenic origin, in oil and gas fields where radium-bearing precipitates formed: 582; presence, in altered limestones, of minerals, probably formed as a result of introduction of hydrothermal solutions, suggests localization of uranium in hydrothermal deposits, possibly of the vein type: 582; radium-bearing precipitates may have been derived from solution and redeposition from the radium-bearing rocks in the

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Kansas City and Arbuckle groups but absence of uranium and radium in equilibrium quantities in these rocks may indicate that uranium was removed from them or radium was introduced into them within the past thousand years; vuggy nature of rock fragments in drill samples suggests that uranium was leached from the rocks only recently, possibly by the drilling fluids when wells were drilled: 582.

Uranium Exploration

See under individual county names and under Index III, Uranium Exploration—Kansas: 578.

Uranium Occurrences

See under individual county names and under Index III, Uranium Occurrences—Kansas: 405, 426, 443, 462, 582, 607.

LOUISIANA

General

Allanite Occurrences—

Mississippi River channel: 40 samples of sand showed small amounts of allanite and/or monazite, usually both, in the heavy mineral separates, these amounts consisting of "Rare," "Rare in one of the two grades analyzed and absent in the other," "Present in amounts less than one percent but fairly common," and up to 1% for allanite and up to 2% for monazite: 609.

Sand deposits: rare occurrences: 619.

Monazite Occurrences—

Lower Mississippi Valley—

Atchafalaya River, mile 78: nonopaque heavy minerals present include fluorite, monazite, corundum, and undetermined minerals in small amounts in alluvium, natural levee silt: 579.

Bayou St. Vincent: nonopaque heavy minerals present include fluorite, monazite, corundum, and undetermined minerals in small amounts in alluvium, substratum gravels, at 250 ft. depth: 579.

Mississippi River Channel: 40 samples of sand showed small amounts of allanite and/or monazite, usually both, in the heavy mineral separates, these amounts consisting of "Rare," "Rare in one of the two grades analyzed and absent in the other," "Present in amounts less than one percent but fairly common," and up to 1% for allanite and up to 2% for monazite: 609.

Sand deposits: rare occurrences: 619.

Thorium Occurrences—

Lower Mississippi Valley—

Atchafalaya River, mile 78: nonopaque heavy minerals present include fluorite, monazite, corundum, and undetermined minerals in small amounts in alluvium, natural levee silt: 579.

Bayou St. Vincent: nonopaque heavy minerals present include fluorite, monazite, corundum, and undetermined minerals in small amounts in alluvium, substratum gravels, at 250 ft. depth: 579.

Mississippi River channel: 40 samples of sand showed small amounts of allanite and/or monazite, usually both, in the heavy mineral separates, these amounts consisting of "Rare," "Rare in one of the two grades analyzed and absent in the other," "Present in amounts less than one percent but fairly common," and up to 1% for allanite and up to 2% for monazite: 609.

Sand deposits: rare occurrences of allanite and monazite: 619.

Allanite Occurrences

See under individual parish names and under Index III, Thorium Occurrences—Louisiana: 577, 609, 619.

Ascension Parish

Monazite Occurrences—

Lower Mississippi Valley—

Donaldsonville: nonopaque heavy minerals present include fluorite, monazite, corundum, and undetermined minerals in small amounts in alluvium, backswamp clay, at 17 ft. depth: 579.

Thorium Occurrences—

Lower Mississippi Valley—

Donaldsonville: nonopaque heavy minerals present include fluorite, monazite, corundum, and undetermined minerals in small amounts in alluvium, backswamp clay, at 17 ft. depth: 579.

East Baton Rouge Parish

Monazite Occurrences—

Lower Mississippi Valley—

Baton Rouge: nonopaque heavy minerals present include fluorite, monazite, corundum, and undetermined minerals in small amounts in (pass. 200 sieve) suspended load, Mississippi River: 579.

Thorium Occurrences—

Lower Mississippi Valley—

Baton Rouge: nonopaque heavy minerals present include fluorite, monazite, corundum, and undetermined minerals in small amounts in (pass. 200 sieve) suspended load, Mississippi River: 579.

Monazite Occurrences

See under individual parish names and under Index III, Thorium Occurrences—Louisiana: 577, 579, 609, 619.

Plaquemines Parish

Allanite Occurrences—

General and in St. Bernard Parish: traces in heavy separates of Mississippi River subdelta sands: 577.

Monazite Occurrences—

General and in St. Bernard Parish: traces in heavy separates of Mississippi River subdelta sands: 577.

Thorium Occurrences—

General and in St. Bernard Parish: allanite and monazite in heavy separates of Mississippi River subdelta sands; traces: 577.

St. Bernard Parish

Allanite Occurrences—

General and in Plaquemines Parish: traces in heavy separates of Mississippi River subdelta sands: 577.

Monazite Occurrences—

General and in Plaquemines Parish: traces in heavy separates of Mississippi River subdelta sands: 577.
Thorium Occurrences—
General and in Plaquemines Parish: allanite and monazite in heavy separates of Mississippi River subdelta sands; traces: 577.
Thorium Occurrences
See under individual parish names and under Index III, Thorium Occurrences—Louisiana: 577, 579, 609, 619.

*MINNESOTA**
General
Radioactive Rocks—
Age Determinations—
Pre-Cambrian rocks: 587.
Radioactivity Studies—
Pre-Cambrian rocks: 587.
Allanite Occurrences
See under individual county names and under Index III, Thorium Occurrences—Minnesota: 559, 585, 586, 610, 615.
Anoka County
Radioactive Soil—
Coon Creek: soil, dune sand, 28 g. Ra × 10^{14}, 27 g. Th × 10^{7}, and 96 Th/Ra × 10^{-5}: 611.
Thorium Occurrences—
Coon Creek: soil, dune sand, 28 g. Ra × 10^{14}, 27 g. Th × 10^{7}, and 96 Th/Ra × 10^{-5}: 611.
Beltrami County
Radioactive Soil—
Bemidji: soil, outwashed plain from late Wisconsin drift, 25 g. Ra × 10^{14}, 34 g. Th × 10^{7}, and 136 Th/Ra × 10^{-5}: 611.
Thorium Occurrences—
Bemidji: soil, outwashed plain from late Wisconsin drift, 25 g. Ra × 10^{14}, 34 g. Th × 10^{7}, and 136 Th/Ra × 10^{-5}: 611.
Carlton County
Radioactive Soil—
Cloquet: soil, moraine from early Wisconsin drift, 13 g. Ra × 10^{14}, 32 g. Th × 10^{7}, and 246 Th/Ra × 10^{-5}: 611.
Thorium Occurrences—
Cloquet: soil, moraine from early Wisconsin drift, 13 g. Ra × 10^{14}, 32 g. Th × 10^{7}, and 246 Th/Ra × 10^{-5}: 611.
Clay County
Radioactive Soil—
Manitoba Junction: soil, Red River Valley, boulder-clay, late Wisconsin drift, 62 g. Ra × 10^{14}, 60 g. Th × 10^{7}, and 97 Th/Ra × 10^{-5}: 611.
Thorium Occurrences—
Manitoba Junction: soil, Red River Valley, boulder-clay, late Wisconsin drift, 62 g. Ra × 10^{14}, 60 g. Th × 10^{7}, and 97 Th/Ra × 10^{-5}: 611.
Cook County
Allanite Occurrences—
Pigeon Point: in diabase: 618.
Thorium Occurrences—
Pigeon Point: allanite in diabase: 618.
Fillmore County
Radioactive Soil—
Preston: soil, loess, 64 g. Ra × 10^{14}, 47 g. Th × 10^{7}, and 73 Th/Ra × 10^{-5}: 611.
Thorium Occurrences—
Preston: soil, loess, 64 g. Ra × 10^{14}, 47 g. Th × 10^{7}, and 73 Th/Ra × 10^{-5}: 611.
Hennepin County
Radioactive Rocks—
Quarry in Minneapolis: limestone showed 0.60 × 10^{-12} g. Ra/g. rock: 561.
Radioactive Soil—
University Farm: soil, till coating on outwashed plain from late Wisconsin drift, 75 g. Ra × 10^{14}, 71 g. Th × 10^{7}, and 95 Th/Ra × 10^{-5}: 611.
Thorium Occurrences—
University Farm: soil, till coating on outwashed plain from late Wisconsin drift, 75 g. Ra × 10^{14}, 71 g. Th × 10^{7}, and 95 Th/Ra × 10^{-5}: 611.
Hubbard County
Radioactive Soil—
Guthrie: soil, outwashed plain from late Wisconsin drift, 27 g. Ra × 10^{14}, 25 g. Th × 10^{7}, and 93 Th/Ra × 10^{-5}: 611.
Thorium Occurrences—
Guthrie: soil, outwashed plain from late Wisconsin drift, 27 g. Ra × 10^{14}, 25 g. Th × 10^{7}, and 93 Th/Ra × 10^{-5}: 611.
Lake County
Allanite Occurrences—
Snowbank Lake: in syenite: 610.
Thorium Occurrences—
Snowbank Lake: allanite in syenite: 610.
(See also St. Louis-Lake Cos.)
Norman County
Radioactive Soil—
Twin Valley: soil, sandy plain, Lake Agassiz, rich in nitrogen, 17 g. Ra × 10^{14}, 28 g. Th × 10^{7}, and 165 Th/Ra × 10^{-5}: 611.
Thorium Occurrences—
Twin Valley: soil, sandy plain, Lake Agassiz, rich in nitrogen, 17 g. Ra × 10^{14}, 28 g. Th × 10^{7}, and 165 Th/Ra × 10^{-5}: 611.
Pine County
Radioactive Soil—
Nickerson: soil, sandy deposit on moraine from early Wisconsin drift, 24 g. Ra × 10^{14}, 32 g. Th × 10^{7}, and 133 Th/Ra × 10^{-5}: 611.
Willow River: soil, outwashed plain from early Wisconsin drift, 20 g. Ra × 10^{14}, 32 g. Th × 10^{7}, and 160 Th/Ra × 10^{-5}: 611.
Thorium Occurrences—
Nickerson: soil, sandy deposit on moraine from early Wisconsin drift, 24 g. Ra × 10^{14}, 32 g. Th × 10^{7}, and 133 Th/Ra × 10^{-5}: 611.
Willow River: soil, outwashed plain from early Wisconsin drift, 20 g. Ra × 10^{14}, 32 g. Th × 10^{7}, and 160 Th/Ra × 10^{-5}: 611.
Pope County
Radioactive Soil—
Cyrus: soil, Red River Valley, boulder-clay, and late Wisconsin drift, 80 g. Ra × 10^{14}, 64 g. Th × 10^{7}, and 80 Th/Ra × 10^{-5}: 611.
Thorium Occurrences—
Cyrus: soil, Red River Valley, boulder-clay, and late Wisconsin drift, 80 g. Ra × 10^{14}, 64 g. Th × 10^{7}, and 80 Th/Ra × 10^{-5}: 611.

* Figures cited for Ra, Th, and Th/Ra in Minnesota soils are given as their Ra, Th, and Th/Ra values *already multiplied* by 10 to the exponent indicated per cc. of soil.

MINNESOTA (contd.)
Radioactive Rocks
See under individual county names and under Index III, Radioactive Rocks—Minnesota: 561, 587.
Radioactive Soil
See under individual county names and under Index III, Radioactive Soil—Minnesota: 611.
Radioactivity Studies
See under individual county names and under Index III, Radioactivity Studies—Minnesota: 587.
Rock County
Radioactive Soil—
Luverne: soil, loess, 64 g. Ra × 10^{14}, 41 g. Th × 10^{7}, and 64 Th/Ra × 10^{-5}: 611.
Thorium Occurrences—
Luverne: soil, loess, 64 g. Ra × 10^{14}, 41 g. Th × 10^{7}, and 64 Th/Ra × 10^{-5}: 611.
St. Louis County
Allanite Occurrences—
Giants Range Batholith: as an accessory mineral in granite: 559.
High Lake area in Vermilion Batholith: as an accessory mineral in segregated magnetite bands: 585.
Vermilion Batholith: in granite: 586.
Thorium Occurrences—
Giants Range Batholith: allanite as an accessory mineral in granite: 559.
High Lake area in Vermilion Batholith: allanite as an accessory mineral in segregated magnetite bands: 585.
Vermilion Batholith: allanite in granite: 586.
St. Louis-Lake Counties
Allanite Occurrences—
Birch Lake: in normal gabbro: 618.
Thorium Occurrences—
Birch Lake: allanite in normal gabbro: 618.
Stearns County
Allanite Occurrences—
Quarry at St. Cloud: as an accessory mineral in Rockville granite: 615.
Thorium Occurrences—
Quarry at St. Cloud: allanite as an accessory mineral in Rockville granite: 615.
Thorium Occurrences
See under individual county names and under Index III, Thorium Occurrences—Minnesota: 559, 585, 586, 610, 611, 615, 618.
Todd County
Radioactive Soil—
Philbrook: soil, outwashed plain from late Wisconsin drift, 20 g. Ra × 10^{14}, 29 g. Th × 10^{7}, and 145 Th/Ra × 10^{-5}: 611.
Thorium Occurrences—
Philbrook: soil, outwashed plain from late Wisconsin drift, 20 g. Ra × 10^{14}, 29 g. Th × 10^{7}, and 145 Th/Ra × 10^{-5}: 611.

MISSISSIPPI RIVER

General
Allanite Occurrences—
Channel between Cairo, Illinois, and Gulf of Mexico: 64 samples taken at intervals between the two points showed small amounts of allanite and/or monazite, usually both, in the heavy mineral separates, the amounts being classified as "Rare," "Rare in one of the two grades analyzed and absent in the other," "Present in amounts less than one per cent but fairly common," and up to 1% for allanite and up to 2% for monazite: 609.
Monazite Occurrences—
Channel between Cairo, Illinois, and Gulf of Mexico: 64 samples taken at intervals between the two points showed small amounts of allanite and/or monazite, usually both, in the heavy mineral separates, the amounts being classified as "Rare," "Rare in one of the two grades analyzed and absent in the other," "Present in amounts less than one per cent but fairly common," and up to 1% for allanite and up to 2% for monazite: 609.
Thorium Occurrences—
Channel between Cairo, Illinois, and Gulf of Mexico: 64 samples taken at intervals between the two points showed small amounts of allanite and/or monazite, usually both, in the heavy mineral separates, the amounts being classified as "Rare," "Rare in one of the two grades analyzed and absent in the other," "Present in amounts less than one per cent but fairly common," and up to 1% for allanite and up to 2% for monazite: 609.
Allanite Occurrences
See above under General and under Index III, Thorium Occurrences—Mississippi River: 609.
Monazite Occurrences
See above under General and under Index III, Thorium Occurrences—Mississippi River: 609.
Thorium Occurrences
See above under General and under Index III, Thorium Occurrences—Mississippi River: 609.

MISSOURI

General
Allanite Occurrences—
Mississippi River channel: 4 samples of sands examined; in heavy mineral separates, 2 samples showed allanite and monazite "Present in amounts less than one per cent but fairly common," and 2 other samples showed only monazite, in one as "Rare" and in the other as "Present in amounts less than one per cent but fairly common": 609.
Limestones, Uranium-bearing—
General: 27.
Southeast part: deposits in Mississippian Spergen limestone stratigraphically controlled: 443.
Monazite Occurrences—
Mississippi River channel: 4 samples of sands examined; in heavy mineral separates, 2 samples showed allanite and monazite "Present in amounts less than one per cent but fairly common," and 2 other samples showed only monazite, in one as "Rare" and in the other as "Present in

amounts less than one per cent but fairly common": 609.
Radioactive Waters—
General:
radioactivity of deep well waters usually lower than that of spring waters: 598; radioactivity of waters and their mineral constituents showed no apparent connection: 598; methods of determination of radioactivity of spring and well waters 598; types of waters studied:
Alkaline: 598; Chalybate: 598; Muriatic or brines: 598; Sulphatic: 598; Sulphur: 598.
Thorium Occurrences—
Mississippi River channel: 4 samples of sands examined; in heavy mineral separates, 2 samples showed allanite and monazite "Present in amounts less than one per cent but fairly common," and 2 other samples showed only monazite, in one as "Rare" and in the other as "Present in amounts less than one per cent but fairly common": 609.
Uranium Occurrences—
General: uranium-bearing limestone: 27.
Flint clays: radioactivity present in those with and without black clay and carbonaceous material: 599.
Pennsylvanian Cherokee shale: possible uranium source which should be investigated further: 462.
Southeast part: uranium in Mississippian Spergen limestone deposits stratigraphically controlled: 443.

Allanite Occurrences
See under individual county names and under Index III, Thorium Occurrences—Missouri: 609.

Barry County
Radioactive Occurrences—
Radium Mine in the Ozark Mountains: samples of bluish colored ore formed radiographs on photographic plates: 612; samples tested by several geologists and showed radioactivity: 612; mine on land owned by John P. Nagel (or Nagle), who began development work there: 612; consignment of ore sent to Germany for analysis: 612.

Black Shales, Uranium-bearing
See under individual county names and under Index III, Black Shales, Uranium-bearing—Missouri: 599.

Boone County
Radioactive waters—
Columbia—
Christian College Deep Well: radioactivity, 1.7×10^{-4} g. U/liter of water: 598.
City Deep Well: radioactivity, 0.25×10^{-4} g. U/liter of water: 598.
Rollins Spring: radioactivity, 4.5×10^{-4} g. U/liter of water: 598.
University Deep Well: radioactivity, 1.5×10^{-4} g. U/liter of water: 598.

Carnotite Occurrences
See under individual county names and under Index III, Carnotite Occurrences—Missouri: 426, 599, 600.

Cass County
Radioactive Occurrences—
Cuttings from oil test well in SW¼ NE¼ Sec. 29, T. 46 N, R. 32 W: slight radioactivity in Lower Pennsylvanian and Upper Mississippian strata: 599.

Cedar County
Radioactive Waters—
Eldorado Springs—
Eldorado Deep Sulphur Well: radioactivity, 0.5×10^{-4} g. U/liter of water: 598.
Eldorado Springs: radioactivity, 1.4×10^{-4} g. U/liter of water: 598.

Clays, Uranium-bearing
See under individual county names and under Index III, Clays, Uranium-bearing—Missouri: 564, 584, 599.

Clinton County
Radioactive Waters—
Plattsburg—
Plattsburg Spring: radioactivity, 3.7×10^{-4} g. U/liter of water: 598.

Crawford County
Radioactivity Determinations—
Bourbon magnetic anomaly on NE flank of Ozark Mts.: study made of Pre-Cambrian rhyolite porphyry section of well core using 40 samples ranging in depth from 1406–2081 ft.:
method of measurement of hard gamma radiation, calibration, accuracy of results: 575;
average radioactive content of different mineral density groups:
a. Mineral density range of 2.50–3.00 g./cm.^{3} showed an average radioactive content for 15 samples in Ra equivalents of grams $\times 10^{-12}$ Ra per g. was 6.52: 575;
b. Mineral density range of 3.00–3.50 g./cm.^{3} showed an average radioactive content for 16 samples in Ra equivalents of grams $\times 10^{-12}$ Ra per g. was 5.44: 575;
c. Mineral density range of 3.50–4.00 g./cm.^{3} showed an average radioactive content for 6 samples in Ra equivalents of grams $\times 10^{-12}$ Ra per g. was 3.08: 575;
d. Mineral density range of 4.00–4.50 g./cm.^{3} showed an average radioactive content for 3 samples in Ra equivalents of grams $\times 10^{-12}$ Ra per g. was 1.90: 575;
results of study showed:
a. Mineral densities are related directly to iron content and increase steadily with depth;
b. Radioactive content decreases directly with depth and with increases in mineral densities;
c. Lower radioactivity counts for mineralized zones are not an effect of absorption but an actual decrease in radioactive content: 575;
results may serve as guides to indicate location of ore in wells since the ionization of potassium granite has been shown to be more than twice that for

MISSOURI (contd.)
the other components taken together and, while the percentage in rhyolite porphyry is lower, probably 3 rather than 3.8, potassium should still supply more of the counts and the low activity of the mineralized zones is entirely explained by leaching out of potassium: 575.
Fluorites, Uranium-bearing
See under individual county names and under Index III, Fluorites, Uranium-bearing—Missouri: 426.
Franklin County
Clays, Uranium-bearing—
Eliza Gelauf property about 5½ mi. SE of Gerald: first radioactive occurrence reported in the state: 584, 599; meta-torbernite chiefly on spheroidal masses of "bad" clay or so-called "sore spots" in flint fire clay: 584, 599.
Meta-torbernite Occurrences—
Eliza Gelauf property about 5½ mi. SE of Gerald: first radioactive occurrences reported in the state: 584, 599; chiefly on spheroidal masses of "bad" clay or so-called "sore spots" in flint fire clay: 584, 599.
Uranium Occurrences—
Eliza Gelauf property about 5½ mi. SE of Gerald: meta-torbernite in tiny scales chiefly on spheroidal masses of "bad" clay or so-called "sore spots" in flint fire clay and associated with barite and small amounts of chalcopyrite and limonite: 584, 599; first radioactive occurrence reported in the state: 584, 599; mineralogical characteristics: 584, 599.
Gasconade County
Clays, Uranium-bearing—
Owensville: meta-torbernite in flint fire clay from sinkhole type pit: 564; first radioactive occurrence reported in the state: 564.
Meta-torbernite Occurrences—
Owensville: in flint fire clay from sinkhole type pit: 564; first radioactive occurrence reported in the state: 564.
Radioactive Occurrences—
Owensville: weak radioactivity in sample with fragments of black carbonaceous material associated with flint clay: no further information available: 599.
Uranium Occurrences—
Owensville: meta-torbernite in flint fire clay from sinkhole type pit: 564; first radioactive occurrence reported in state: 564.
Greene County
Radioactive Waters—
Springfield—
Deep Well: radioactivity, 0.1×10^{-4} g. U/liter of water: 598.
Howard County
Radioactive Waters—
Fayette—
Boons Lick Spring: radioactivity, 4.6×10^{-4} g. U/liter of water: 598.
Jackson County
Radioactive Waters—
Independence—
Cusenbery Spring: radioactivity, 12.6×10^{-4} g. U/liter of water: 598.
Kansas City, 5 mi. E of—
Lake Spring: radioactivity, 48.2×10^{-4} g. U/liter of water: 598.
Johnson County
Radioactive Waters—
Warrensburg—
Electric Spring: radioactivity, 2.25×10^{-4} g. U/liter of water: 598.
Pertle Spring: radioactivity, 2.9×10^{-4} g. U/liter of water: 598.
Limestones, Uranium-bearing
See under individual county names and under Index III, Limestones, Uranium-bearing—Missouri: 27, 443, 600.
Meta-torbernite Occurrences
See under individual county names and under Index III, Meta-torbernite Occurrences—Missouri: 564, 584, 599.
Monazite Occurrences
See under individual county names and under Index III, Thorium Occurrences—Missouri: 609.
Morgan County
Radioactive Waters—
Versailles—
Alum Well: radioactivity, 0.8×10^{-4} g. U/liter of water: 598.
Oregon County
Radioactive Waters—
Greer—
Greer Springs: radioactivity, 0.4×10^{-4} g. U/liter of water: 598.
Origin of Carnotite Occurrences
See under individual county names and under Index III, Origin—Carnotite Occurrences—Missouri: 426.
Origin of Uranium Occurrences
See under individual county names and under Index III, Origin—Uranium Occurrences—Missouri: 426.
Prospectors' Guides
See under individual county names and under Index III, Prospectors' Guides—Missouri: 599.
Radioactive Occurrences
See under individual county names and under Index III, Radioactive Occurrences—Missouri: 599, 612.
Radioactive Springs
See under individual county names and under Index III, Radioactive Springs—Missouri: 294. See also, Radioactive Waters—Missouri: 598.
Radioactive Waters
See under individual county names and under Index III, Radioactive Waters—Missouri: 294, 598.
Radioactivity Determinations
See under individual county names and under Index III, Radioactivity Determinations—Missouri: 575.
Ste. Genevieve County
Black Shales, Uranium-bearing—
Charles Bussen quarry N of Ste. Genevieve: highly radioactive black carbonaceous shale parting between two limestone beds near top of quarry face shows radioactivity

of 0.37% eU; shale phosphatic but uranium mineral unidentified; also contained vanadium in clay mineral, illite: 599; uranium in finely disseminated carbonaceous material and purple fluorite contained in the Mississippian Spergen limestone, which also encloses thin black shale beds molded into stylolitic structures and containing 0.6% uranium or more than 100 times greater than in the average shales of the Chattanooga and Pennsylvanian type; carnotite in limestone adjacent to black shale may have been leached from shale and transported by groundwater: 426.
Carnotite Occurrences—
Charles Bussen quarry N of Ste. Genevieve: as thin film along joint surface in limestone of Spergen (Mississippian) formation: 599; uranium in finely disseminated carbonaceous material and purple fluorite contained in the Mississippian Spergen limestone, which also encloses thin black shale beds molded into stylolitic structures and containing 0.6% uranium or more than 100 times greater than in the average shales of the Chattanooga and Pennsylvanian type; carnotite in limestone adjacent to the black shale may have been leached from shale and transported by groundwater: 426.
Ste. Genevieve, 5½ mi. N of: 600.
Fluorites, Uranium-bearing—
Charles Bussen quarry N of Ste. Genevieve: uranium in finely disseminated carbonaceous material and purple fluorite contained in the Mississippian Spergen limestone, which also encloses thin black shale beds molded into stylolitic structures and containing 0.6% uranium or more than 100 times greater than in the average shales of the Chattanooga and Pennsylvanian type; carnotite in limestone adjacent to the black shale may have been leached from shale and transported by groundwater: 426.
Limestone, Uranium-bearing—
Charles Bussen quarry N of Ste. Genevieve: uranium in finely disseminated carbonaceous material and purple fluorite contained in the Mississippian Spergen limestone, which also encloses thin black shale beds molded into stylolitic structures and containing 0.6% uranium or more than 100 times greater than in the average shales of the Chattanooga and Pennsylvanian type; carnotite in limestone adjacent to black shale may have been leached from shale and transported by groundwater: 426.
Ste. Genevieve, 5½ mi. N of: carnotite: 600.
Shales, Uranium-bearing—
Ste. Genevieve, 5½mi. N of: carnotite: 600.
Uranium Occurrences—
Charles Bussen quarry N of St. Genevieve: carnotite as thin film along joint surface in limestone of Spergen (Mississippian) formation: 599; highly radioactive black carbonaceous shale parting between two limestone beds near top of quarry face shows radioactivity of 0.37% eU; shale phosphatic but uranium mineral not identified; also contained vanadium in the clay mineral, illite: 599; uranium in finely disseminated carbonaceous material and purple fluorite contained in the Mississippian Spergen limestone, which also encloses thin black shale beds molded into stylolitic structures and containing 0.6% uranium or more than 100 times greater than in the average shales of the Chattanooga and Pennsylvanian type; carnotite in limestone adjacent to black shale may have been leached from shale and transported by groundwater: 426.
Ste. Genevieve, 5½ mi. N of: carnotite in limestone and shale: 600.
Saline County
Radioactive Springs—
Sweet Springs: uranium: 294.
Radioactive Waters—
Sweet Springs—
Akesion Water: radioactivity, 3.4×10^{-4} g. U/liter of water: 598.
Sweet Springs: uranium in radioactive springs: 294; radioactivity, 23.7×10^{-4} g. U/liter of water: 598.
Uranium Occurrences—
Sweet Springs: uranium in radioactive springs: 294.
Shales, Uranium-bearing
See under individual county names and under Index III, Shales, Uranium-bearing—Missouri: 600.
Thorium Occurrences
See under individual county names and under Index III, Thorium Occurrences—Missouri: 609.
Uranium Occurrences
See under individual county names and under Index III, Uranium Occurrences—Missouri: 27, 294, 426, 443, 462, 564, 584, 599, 600.
Vernon County
Radioactive Waters—
Nevada—
The Artesian Well: radioactivity, 4.5×10^{-4} g. U/liter of water: 598.
Iron Spring: radioactivity, 2.0×10^{-4} g U/liter of water: 598.
White Sulphur Spring: radioactivity, 2.3×10^{-4} g. U/liter of water: 598.

NEBRASKA

Agate, Uranium-bearing
See under individual county names and under Index III, Agate, Uranium-bearing—Nebraska: 573.
Dawes County
Agate, Uranium-bearing—
Hay Springs, 50 mi. from: 573.
Uranium Occurrences—
Hay Springs, 50 mi. from: uranium-bearing fluorescent agate: 573.
Monazite Occurrences
See under individual county names and under Index III, Thorium Occurrences—Nebraska: 11.
Seward County
Monazite Occurrences
Milford: trace: 11.

NEBRASKA (contd.)
Thorium Occurrences—
Milford: monazite, trace: 11.
Thorium Occurrences
See under individual county names and under Index III, Thorium Occurrences—Nebraska: 11.
Uranium Occurrences
See under individual county names and under Index III, Uranium Occurrences—Nebraska: 573.

NORTH DAKOTA

General
Becquerelite Occurrences—
General: hydrous uranium oxide, probably becquerelite, in lignites: 493.
Lignites, Uranium-bearing—
General: 27, 62; uranium mineral, probably becquerelite: 493.
Southwest part: uranium in Paleocene and Eocene lignites with greatest concentrations in first group of beds below the Paleocene-Eocene unconformity: 426; uranium content of lignite beds varies but some contain slightly more than 0.01%: 426; origin of uranium in Paleocene and Eocene lignites may be by leaching from volcanic ash in White River formation and introduction into the lignite by surface waters in post-Paleocene time but the even distribution of uranium in lignite, as shown by autoradiograph of one North Dakota specimen, and the absence of apparent concentration of uranium in fracture planes in area suggest uranium was present before coalification: 426; deposits stratigraphically controlled: 443.
Uranium Occurrences—
General: uranium-bearing lignite: 27, 62; uranium mineral, probably becquerelite in lignites: 493.
Bibliography of U.S.G.S. reports: 572.
Lignites, Uranium-bearing: 27, 62, 426, 443, 493.
Southwest part: uranium in Paleocene and Eocene lignites with greatest concentrations in first group of beds below the Paleocene-Eocene unconformity: 426; uranium content of lignite beds varies but some contain slightly more than 0.01%: 426; origin of uranium in Paleocene and Eocene lignites may be by leaching from volcanic ash in White River formation and introduction into the lignite by surface waters in post-Paleocene time but the even distribution of uranium in lignite as shown by autoradiograph of one North Dakota specimen, and the absence of apparent concentration of uranium on fracture planes in area suggest uranium was present before coalification: 426; uranium-bearing lignites; deposits stratigraphically controlled: 443.
Becquerelite Occurrences
See under individual county names and under Index III, Becquerelite Occurrences—North Dakota: 493.
Bibliographies
Uranium Occurrences
Bibliography of U.S.G.S. reports: 572.
Lignites, Uranium-bearing
See under individual county names and under Index III, Lignites, Uranium-bearing—North Dakota: 27, 62, 426, 443, 493.
Origin of Uranium Occurrences
See under individual county names and under Index III, Origin—Uranium Occurrences—North Dakota: 426.
Origin of Uranium-bearing Lignites
See under individual county names and under Index III, Origin—Lignites, Uranium-bearing—North Dakota: 426.
Uranium Occurrences
See under individual county names and under Index III, Uranium Occurrences—North Dakota: 27, 62, 426, 443, 493.
Bibliography of U.S.G.S. reports: 572.

OKLAHOMA

General
Black Shales, Uranium-bearing—
Checkerboard and Fort Scott limestones: uranium in phosphatic nodules in black shales: 405.
Northeast part: uranium in Chattanooga shales; radioactivity equivalent to that of the type Chattanooga shales in Tennessee: 426.
Oil wells: gamma ray logs show black shales equivalent in radioactivity to type Chattanooga shale in Tennessee and its Woodford chert equivalent: 426.
Pennsylvanian black shales at top of Checkerboard limestone member of Coffeyville formation and of Fort Scott (or Oswego) limestone: uranium in phosphate nodules: 462.
Pennsylvanian shales: uranium and thorium in black shales with highest content in the phosphatic nodules: 426.
South central part: uranium in Woodford chert; radioactivity equivalent to that of the type Chattanooga shales in Tennessee: 426.
Woodford chert: uranium: 405, 462.
Phosphorites, Uranium-bearing—
Pennsylvanian black shales at top of Checkerboard limestone member of Coffeyville formation and of Fort Scott (or Oswego) limestone: uranium in phosphate nodules: 462.
Woodford chert: uranium: 462.
Radioactive Asphaltite
West part: nodular asphaltite-like bitumen samples with abnormally high radioactivity count: 574.
Radioactive Occurrences—
West part: nodular asphaltite-like bitumen samples with abnormally high radioactivity count: 574.
Uranium Occurrences—
Bandera shale: possible uranium source which should be investigated further: 462.
Caney shale: possible uranium source which should be investigated further: 462.
Checkerboard and Fort Scott limestones:

uranium-bearing phosphatic nodules in black shale: 405.
North central part: uraniferous deposits in sandstone stratigraphically controlled: 443.
Northeast part: uranium in Chattanooga shales; radioactivity equivalent to that of the type Chattanooga shales in Tennessee: 426.
Oil wells: gamma ray logs show black shales equivalent in radioactivity to type Chattanooga shale in Tennessee and its Woodford chert equivalent: 426.
Pennsylvanian black shales at top of Checkerboard limestone member of Coffeyville formation and of Fort Scott (or Oswego) limestone: uranium in phosphate nodules: 462.
Pennsylvanian shales: uranium and thorium in black shales with highest content in the phosphatic nodules: 426.
South central part: uranium in Woodford chert; radioactivity equivalent to that of the type Chattanooga shales in Tennessee: 426.
Woodford chert: uranium: 462; uranium-bearing black shales: 405.

Asphalts, Uranium-bearing
See under individual county names and under Index III, Asphalts, Uranium-bearing—Oklahoma: 509.

Black Shales, Uranium-bearing
See under individual county names and under Index III, Black Shales, Uranium-bearing—Oklahoma: 405, 426, 462.

Comanche County
Rare Earths, Thorium-bearing—
Wichita Mountains: samples with columbite which may be accompanied by samarskite or pitchblende: 623.
Rare Earths, Uranium-bearing—
Wichita Mountains: 583; samples with columbite which may be accompanied by samarskite or pitchblende: 623.
Thorium Occurrences—
Quanah granite in Quanah Mountain in Wichita Mts.: uranium and thorium in metamict and fresh zircon in pegmatite: 595.
Wichita Mountains: traces of uranium and thorium in pegmatite dike associated with zircon crystals: 574; rare earths with columbite which may be accompanied by samarskite or pitchblende: 623.
Uranium Occurrences—
Quanah granite in Quanah Mountain in Wichita Mts.: uranium and thorium in metamict and fresh zircon in pegmatite: 595.
Wichita Mountains: traces of uranium and thorium in pegmatite dike associated with zircon crystals: 574; rare earths with columbite which may be accompanied by samarskite or pitchblende: 623; uranium in rare earths: 583.
Zircon, Thorium-bearing—
Quanah granite in Quanah Mountain in Wichita Mts.: uranium and thorium in metamict and fresh zircon in pegmatite: 595.
Zircon, Uranium-bearing—
Quanah granite in Quanah Mountain in Wichita Mts.: uranium and thorium in metamict and fresh zircon in pegmatite: 595.

Greater Seminole Area
Radioactivity Surveys—
Allen sandstone (Pennsylvanian): lithology: similar to Senora sand; radioactivity interpretation: gamma ray: changes from well to well and area to area: 597.
Bartlesville formation (Pennsylvanian): lithology: micaceous sand with thin shale and silty streaks: 597; radioactivity interpretation: gamma ray: minimum to intermediate intensity value depending on shale content: 597, neutron: low to medium intensity value: 597.
Basal Wewoka sand (Pennsylvanian): lithology: conglomerate, cherty sand; thin shale lenses: 597; radioactivity interpretation: gamma ray: minimum intensity value; fairly uniform except for thin shale beds: 597, neutron: medium curve intensity value: 597.
Booch Group (Pennsylvanian): lithology: sandstone with pyrite and mica flakes: 597; radioactivity interpretation: gamma ray: low to medium intensity value depending on contamination: 597, neutron: low to high curve intensity value: 597.
Brown lime (Pennsylvanian): lithology: limestone: 597; radioactivity interpretation: gamma ray: minimum to intermediate intensity value: 597, neutron: medium to high intensity value: 597.
Calvin series (Pennsylvanian): lithology: sandstone with many thin shale partings: 597; radioactivity interpretation: gamma ray: low curve intensity value with thin shale indications: 597, neutron: low to high intensity value: 597.
Caney group (Pennsylvanian): lithology: black splintery flakey shale with limestone lintels and occasional pyritic streaks: 597; radioactivity interpretation: gamma ray: records as common shale with frequent extreme intensity value: 597, neutron: low intensity value, typical shale: 597.
Cromwell-Union Valley formations (Pennsylvanian): Cromwell sand: lithology: sandstone with some shale streaks: 597; radioactivity interpretation: gamma ray: low to medium intensity value depending on contaminating material: 597, neutron: low to high intensity value: 597.
Union Valley formation: lithology: gray to black, fine to medium, angular sandy lime: 597; radioactivity interpretation: gamma ray: usually low intensity value: 597, neutron: medium to high curve intensity value: 597.
Earlsboro-Red Fork formation (Pennsylvanian): lithology: sandstone with thin shale streaks: 597; radioactivity interpretation: gamma ray: usually minimum intensity value: 597, neutron: low to high intensity value: 597.
Gilcrease formation (Pennsylvanian): li-

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thology: sandstone with glauconitic nodules: 597; radioactivity interpretation: gamma ray: minimum to intermediate intensity value depending on contaminating material: 597, neutron: irregular to medium intensity value: 597.
Henryetta coal (Pennsylvanian): lithology: dark gray to black carbonaceous shales with occasional thin coal seam: 597; radioactivity interpretation: gamma ray: higher curve intensity value than shale zones above and below: 597, neutron: normal shale intensity value: 597.
Hunton group (Silurian-Devonian): lithology: limestone (part of it cherty): 597; radioactivity interpretation: gamma ray: low to intermediate intensity value depending on amount of contaminating material: 597, neutron: medium to high intensity value: 597.
McAlester formation (Pennsylvanian): lithology: sandstone separated by shale streaks: 597; radioactivity interpretation: gamma ray: intermediate intensity value denoting lensing or contamination: 597, neutron: low to medium intensity value: 597.
Mayes formation (Mississippian): lithology: brown, finely crystalline, calcareous shale to argillaceous limestone and overlain by the Mississippian Caney consisting of black to brown shale: 597; radioactivity interpretation: gamma ray: irregular intermediate to high intensity value: 597, neutron: low to high intensity value depending on percentage of contamination: 597.
Misener formation (Mississippian): lithology: sandstone, often calcareous to dolomitic: 597; radioactivity interpretation: gamma ray: minimum intensity value: 597, neutron: low to high intensity value: 597.
Savanna formation (Pennsylvanian): lithology: interbedded fine-grained sandstone and shale, very lenticular: 597; radioactivity interpretation: gamma ray: medium curve intensity value: 597, neutron: low intensity value: 597.
Senora limestone (Pennsylvanian): lithology: limestone, a geological marker: 597; radioactivity interpretation: gamma ray: low intensity value: 597, neutron: high intensity value: 597.
Senora (Skinner) formation (Pennsylvanian): lithology: sandstone: 597; radioactivity interpretation: gamma ray: low to medium intensity value; higher where there are shale streaks: 597, neutron: low to high intensity value: 597.
Simpson group (Ordovician): lithology: sands, dolomite; green shales: 597; radioactivity interpretation: gamma ray: low intensity value for sands and dolomite, and medium to high for green shales: 597, neutron: high to low intensity value for sands and dolomite, and usually low intensity value for green shales: 597.
Sycamore limestone (Mississippian): lithology: limestone: 597; radioactivity interpretation: gamma ray: medium to low intensity value: 597, neutron: medium to high intensity value: 597.
Sylvan group (Ordovician): lithology: green to green-gray fine textured shale: 597; radioactivity interpretation: gamma ray: average shale intensity value: 597, neutron: normal low shale intensity value: 597.
Thurman formation (Pennsylvanian): lithology: sandstone, sometimes slightly glauconitic or with thin shale and silty streaks: 597; radioactivity interpretation: gamma ray: low to medium intensity value: 597, neutron: low to medium intensity value: 597.
Viola group (Ordovician): lithology: limestone: 597; radioactivity interpretation: gamma ray: low intensity value: 597, neutron: high to low intensity value: 597.
Wapanucka formation (Pennsylvanian): lithology: oolitic limestone: 597; radioactivity interpretation: gamma ray: usually low intensity value: 597, neutron: medium to high intensity value: 597.
Woodford group (Mississippian): lithology: black, non-calcareous shale with irregular pyrite nodules: 597; radioactivity interpretation: gamma ray: high to extreme intensity value; excellent marker: 597, neutron: low curve intensity value: 597.
Nowata County
Radioactive Rocks—
Well (not named): three core samples of Pennsylvanian Bartlesville sandstones at 494 ft. depth, $0.82 \pm .06 \times 10^{-12}$ g. Ra/g. rock; at 505 ft. depth, $0.58 \pm .05 \times 10^{-12}$ g. Ra/g. rock; at 512 ft. depth, $0.51 \pm .05 \times 10^{-12}$ g. Ra/g. rock: 561.
Pawnee County
Asphalts, Uranium-bearing—
Staneart property: in Permian sandstone: 509.
Uranium Occurrences—
Staneart property: uraniferous asphalt deposits in Permian sandstone: 509.
Phosphorites, Uranium-bearing
See under individual county names and under Index III, Phosphorites, Uranium-bearing—Oklahoma: 462.
Pontotoc County
Radioactive Crude Oil—
Well-Moore No. 1A Harper of Magnolia Petroleum Co. at Fitts pool produced from Ordovician Viola-Simpson fm.: oil sample gave 37 sp. gr. in Deg. A.P.I.; 0.143×10^{-12} curies radon/g. oil; 0.005×10^{-12} g. Ra/g. oil; and 28.6 radon:radium ratio: 561.
Well-Moore No. 1B Harper of Magnolia Petroleum Co. at Fitts pool produced from Pennsylvanian Cromwell fm.: oil sample gave 37 sp. gr. in Deg. A.P.I.; 0.049×10^{-12} curies radon/g. oil; 0.007×10^{-12} g. Ra/g. oil; and 7.0 radon:radium ratio: 561.
Well-Moore No. 7 Schauers of Magnolia Petroleum Co. at Fitts pool produced from Ordovician Viola-Simpson fm.: oil sample gave 35 sp. gr. in Deg. A.P.I.; 0.087 ×

10^{-12} curies radon/g. oil; 0.019 × 10^{-12} g. Ra/g. oil; and 4.6 radon:radium ratio: 561.
Well-Moore No. 7A Schauers of Magnolia Petroleum Co. at Fitts pool produced from Pennsylvanian Cromwell fm.: oil sample gave 37 sp. gr. in Deg. A.P.I.; 0.136 × 10^{-12} curies radon/g. oil; 0.034 × 10^{-12} g. Ra/g. oil; and 4.0 radon:radium ratio: 561.
Radioactive Rocks—
Well-Moore No. 1A Harper at Fitts pool: sample of cuttings of Ordovician shaly limestone of Viola fm. at 3,810–35 ft. depth, 0.78 ± 0.06 × 10^{-12} g. Ra/g. rock: 561; sample of cuttings of Ordovician shaly limestone, sandstone of the McLish fm. at 4,245–81 ft. depth, 0.29 ± .03 × 10^{-12} g. Ra/g. rock: 561; sample of cuttings of Ordovician limestone at 4,365–73 ft. depth, 0.18 ± .03 × 10^{-12} g. Ra/g. rock: 561.
Well-Moore No. 7 Schauers at Fitts pool: sample of cuttings of Ordovician shaly limestone of Viola fm. at 3,780–00 ft. depth, 1.30 ± .07 × 10^{-12} g. Ra/g. rock: 561; sample of cuttings of Pennsylvanian shaly sandstone of Cromwell fm. at 2,510–40 ft. depth, 0.67 ± .05 × 10^{-12} g. Ra/g. rock: 561; sample of cuttings of Ordovician limestone, shale, quartz of McLish fm. at 4,265–70 ft. depth, 0.31 ± .03 × 10^{-12} g. Ra/g. rock: 561; sample of cuttings of Ordovician dolomite at 4,370–75 ft. depth, 0.29 ± .03 × 10^{-12} g. Ra/g. rock: 561.
Radioactive Asphaltite
See under individual county names and under Index III, Radioactive Asphaltite—Oklahoma: 574.
Radioactive Crude Oil
See under individual county names and under Index III, Radioactive Crude Oil—Oklahoma: 561.
Radioactive Occurrences
See under individual county names and under Index III, Radioactive Occurrences—Oklahoma: 574.
Radioactive Rocks
See under individual county names and under Index III, Radioactive Rocks—Oklahoma: 561.
Radioactivity Surveys
See under individual county names and under Index III, Radioactivity Surveys—Oklahoma: 597.
Rare Earths, Thorium-bearing
See under individual county names and under Index III, Rare Earths, Thorium-bearing—Oklahoma: 623.
Rare Earths, Uranium-bearing
See under individual county names and under Index III, Rare Earths, Uranium-bearing—Oklahoma: 583, 623.
Thorium Occurrences
See under individual county names and under Index III, Thorium Occurrences—Oklahoma: 574, 595, 623.
Uranium Occurrences
See under individual county names and under Index III, Uranium Occurrences—Oklahoma: 405, 426, 443, 462, 509, 574, 583, 595, 623.
West Part
Radioactive Asphaltite—
Nodular asphaltite-like bitumen samples: abnormally high radioactivity count: 574.
Radioactive Occurrences—
Nodular asphaltite-like bitumen samples: abnormally high radioactivity count: 574.
Zircon, Thorium-bearing
See under individual county names and under Index III, Zircon, Thorium-bearing—Oklahoma: 595.
Zircon, Uranium-bearing
See under individual county names and under Index III, Zircon, Uranium-bearing—Oklahoma: 595.

SOUTH DAKOTA

General
Allanite Occurrences—
Black Hills: Pre-Cambrian granite domes: 608.
Autunite Occurrences—
Black Hills: in pegmatites: 570.
Becquerelite Occurrences—
General: hydrous uranium oxide, probably becquerelite, in lignites: 493.
Lignites, Uranium-bearing—
General: 27, 62; origin of uranium deposits, probably due to downward migration from radioactive tuffs in overlying Oligocene White River formation and Arikaree formation of Miocene age: 261; uranium mineral, probably becquerelite: 493.
Northwest part: uranium in Paleocene and Eocene lignites with greatest concentrations in first group of beds below the Paleocene-Eocene unconformity: 426; uranium content of lignite beds varies but some contain slightly more than 0.01%: 426; origin of uranium in Paleocene and Eocene lignites may be by leaching from volcanic ash in White River formation and introduction into the lignite by surface waters in post-Paleocene time, but the even distribution of uranium in lignite, as shown by autoradiograph of one North Dakota specimen, and the absence of apparent concentration of uranium in fracture planes in area suggest uranium was present before coalification: 426; deposits stratigraphically controlled: 443.
Monazite Occurrences—
Black Hills: in pegmatites: 570; in placers: 606; small traces in gold placers: 567.
Thorium Occurrences—
Black Hills—
Black Hills: monazite in placers: 606; monazite with uranium minerals in pegmatites: 570; small traces of monazite in gold placers: 567; general geology of area: 570.
Pre-Cambrian granite domes: allanite: 608.
Torbernite Occurrences—
Black Hills: in pegmatites: 570.
Uraninite Occurrences—
Black Hills: in pegmatites: 570.

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Uranium Occurrences—
General: 25; uranium-bearing lignite: 27; origin of uranium in lignites, probably due to downward migration from radioactive tuffs in overlying Oligocene White River formation and Arikaree formation of Miocene age: 261; uranium mineral, probably becquerelite, in lignites: 493; uranocircite: 592.
Bibliography of U.S.G.S. reports: 572.
Black Hills: autunite, monazite, torbernite, and uraninite in pegmatites: 570; general geology of area: 570; uranium-bearing Oligocene White River formation caps many hills and is overlain by slightly radioactive Miocene sandstone: 261. Uranium deposits in Custer, Lawrence, and Pennington Cos. (See county listings for specific locations): 621.
Lignites, Uranium-bearing: 27, 62, 261, 426, 443, 493.
Northwest part: uranium in Paleocene and Eocene lignites with greatest concentrations in first group of beds below the Paleocene-Eocene unconformity: 426; uranium content of lignite beds varies but some contain slightly more than 0.01%: 426; origin of uranium in Paleocene and Eocene lignites may be by leaching from volcanic ash in White River formation and introduction into the lignite by surface waters in post-Paleocene time, but the even distribution of uranium in lignite, as shown by autoradiograph of one North Dakota specimen, and the absence of apparent concentration of uranium on fracture planes in area suggest uranium was present before coalification: 426; uranium-bearing lignites; deposits stratigraphically controlled: 443.
Uranocircite Occurrences—
General: 592.
Allanite Occurrences
See under individual county names and under Index III, Thorium Occurrences—South Dakota: 608.
Autunite Occurrences
See under individual county names and under Index III, Autunite Occurrences—South Dakota: 78, 82, 568, 570, 602, 606, 614, 617, 620, 621.
Becquerelite Occurrences
See under individual county names and under Index III, Becquerelite Occurrences—South Dakota: 493.
Bibliographies
Uranium Occurrences—
Bibliography: annotated and probably including a few older papers on uranium occurrences: 601.
Bibliography of U.S.G.S. reports: 572.
Black Hills
Uranium Occurrences—
General: uranium deposits in Custer, Lawrence, and Pennington Cos. (See county listings for specific locations): 621.
Bibliography: annotated, with some references to uranium occurrences: 601.
Butte County
Radioactive Occurrences—
Area between South Dakota and Wyoming border near Belle Fourche: radioactive rock, possibly uranium-bearing: 628; some ore samples collected by Homestake Mining Co. at Lead, South Dakota: 628; negotiations for leases and exploratory drilling rights underway: 628.
Carnotite Exploration
See under individual county names and under Index III, Carnotite Exploration-South Dakota: 603.
Carnolite Occurrences
See under individual county names and under Index III, Carnotite Occurrences—South Dakota: 53, 560, 603.
Custer County
Autunite Occurrences—
Black Hills—
Custer: 82; with monazite, torbernite, and uraninite in pegmatites: 606.
Harney Peak Region—
Harney Peak granite from area near Custer: occurs with monazite, torbernite, and uraninite in the amblygonite-type and spodumene-type pegmatite phases of the granite and in quartz veins with torbernite: 620.
Spokane: 82.
Microlite Occurrences—
Black Hills—
Custer District—
Tin Mountain mine: microlite reported in very small quantities in pegmatite: 604.
Monazite Occurrences—
Black Hills—
Custer: with autunite, torbernite, and uraninite in pegmatites: 606.
Harney Peak Region—
Harney Peak granite from area near Custer: occurs with autunite, torbernite, uraninite in amblygonite-type and spodumene-type pegmatite phases of the granite and alone in placer deposits: 620.
Thorium Occurrences—
Black Hills—
Custer: autunite, torbernite, uraninite, and monazite in pegmatites: 606.
Harney Peak Region—
Harney Peak granite from area near Custer: monazite occurs with autunite, torbernite, uraninite in amblygonite-type and spodumene-type pegmatite phases of the granite and alone in placer deposits: 620.
Torbernite Occurrences—
Black Hills—
Custer: with autunite, monazite, and uraninite in pegmatites: 606.
Harney Peak Region—
Harney Peak granite from area near Custer: occurs with autunite, monazite, uraninite in amblygonite-type and spodumene-type pegmatite phases of the granite and with autunite in quartz veins: 620.

Uraninite Occurrences—
Black Hills—
Custer: with autunite, monazite, and torbernite in pegmatites: 606.
Custer Mountain (Skookum) feldspar mine: reported as rare in core in pegmatite: 604.
Harney Peak Region—
Harney Peak granite from area near Custer: occurs with autunite, monazite, torbernite in the amblygonite-type and spodumene-type pegmatite phases of the granite: 620.
Uranium Occurrences—
Black Hills—
Custer: autunite: 82; autunite, torbernite, uraninite, and monazite in pegmatites: 606.
Custer District—
Tin Mountain mine: microlite reported in very small quantities in pegmatite: 604.
Custer Mountain (Skookum) feldspar mine: uraninite reported as rare in core in pegmatite: 604.
Harney Peak Region—
Harney Peak granite from area near Custer: uranium minerals occur with mica in the pegmatitic phases of this granite: amblygonite-type pegmatite phase shows autunite, monazite, torbernite, and uraninite: 620, spodumene-type pegmatite phase shows autunite, monazite, torbernite, and uraninite: 620; paragenesis of all minerals in area: 620; placer deposits show monazite: 620; quartz veins show autunite, torbernite: 620.
Spokane: autunite: 82.
Fall River County
Carnotite Exploration—
Suggestions to Prospectors: all carnotite exposures should be examined with Geiger counters or scintillometers, especially exposures of thin-bedded sandstone within 30 ft. above and 70 ft. below the carbonaceous shale: 603; all benches between massive sandstone beds should be examined with Geiger counters or scintillometers and trenches dug in areas of high count: 603; all exposures containing carnotite parallel to bedding should be prospected by blasting: 603; all exposed high grade orebodies should be mined out to get the trend of the deposits: 603; carbonaceous shale may serve as an ore guide since favorable zones for carnotite appear to lie 20–30 ft. above the shale or at three levels below it at 25–30 ft., 45–50 ft., and 65–70 ft. respectively: 603; carnotite-bearing rock mined during prospecting should be sorted to obtain ore containing 0.1% or more uranium in order to determine the percentage of salable ore mineable from each deposit: 603; many carnotite-bearing samples are out of equilibrium indicating that higher grade ore may be found underground beyond areas of surface leaching: 603.
Carnotite Occurrences—
Coal Canyon, 4 mi. NW of Craven Canyon: carnotite in Lakota formation; material of probable ore grade, averaging about one foot thick, crops out on two sides of a pointed spur or bench, indicating a fair tonnage of ore there although much prospecting remains to be done; ratio of U_3O_8 to V_2O_5 in carnotite may be about 1 to 2: 560.
Craven Canyon, 8 mi. N of Edgemont: carnotite as yellow fillings between sand grains, joint fillings, and as thin coatings at three horizons within the lower 150 ft. of the Lakota formation in deposits roughly parallel to the bedding or parallel to the long axes of broad lenses of thin-bedded sandstone, and similar to the uranium occurrences of the Colorado Plateau; ratio of U_3O_8 to V_2O_5 in carnotite is about 2 to 1: 560; carnotite deposits in Lakota sandstone first discovered in 1951: 603; accessibility of carnotite prospects: 603; descriptions of individual carnotite prospects: 603; geology: carnotite prospects in Lakota sandstone overlain by Fuson shale on higher ridges and underlain by Morrison formation exposed in valleys; beds consist of uniformly fine-grained quartz and appreciable amounts of interstitial white clay; carnotite and limonite stains abundant on sandstone throughout area and manganese oxides coat fractures and occur as spots in carnotite-bearing sandstone; unidentified dark to olive green stain coats sandstone near carnotite and chemical tests show presence of uranium and vanadium: 603; localization of carnotite deposits in lower 100 to 150 ft. of Lakota sandstone in three favorable zones: 603; location of carnotite prospects: 603; mineralogy: 603; ore deposits: 603; size and shape of carnotite deposits: 603; suggestions for prospecting on carnotite claims: 603.
Alice claim, adjoins Clara and Joan claims and is across canyon to west of Eunice claim: discovery pit exposes 3 to 5 ft. vertical thickness of carnotite ore that can be traced for about 40 ft. from the strike and may extend further; no samples taken but ore may be equivalent in grade to that in Dagmar claim, of which occurrence is almost a duplicate: 603.
Dagmar claim, adjoins NE side of Betty claim and is across canyon N of Eunice claim: discovery pit, 5 ft. deep, at S corner of claim; carnotite at discovery pit and in float blocks with half-inch thick stringers of carnotite ore parallel to bedding and on steeply dipping joints and fractures, and disseminated throughout ore zone; channel sample of carnotite-bearing gray sandstone contained 0.062% eU and 0.039% U: 603.
Eggshell claim, adjoins Ophelia claim on north: carnotite occurs near fracture zone where two claims adjoin or overlap in two lenses about 20 to 25 ft. below

SOUTH DAKOTA (contd.)
carbonaceous shale; ore in one lense estimated to be of higher grade than that of sample from Ophelia claim which contained 0.14% eU, 0.20% U, and 0.10% V: 603.
Eunice claim, between Imogene and Lucy claims: discovery pit located about 400 ft. NW of Imogene discovery pit and at base of 50-ft. cliff of massive sandstone about 35 ft. above base of Lakota sandstone; carnotite present at discovery pit, also in high grade streaks as much as 0.05 ft. thick parallel to bedding and as disseminated blebs and stains scattered throughout massive sandstone; one vertical channel sample contained 0.024% eU and 0.015% U: 603.
Flora claim, adjoins Gertrude claim: carnotite stains visible about 20 ft. above papery-weathering, carbonaceous shale horizon and about 10 ft. below another thin carbonaceous shale, and may be the continuation of carnotite zone on Gertrude claim; second zone about 15–20 ft. above non-papery carbonaceous shale; carnotite-bearing talus blocks common below the cliff; no careful inspection or sampling carried out: 603.
Gertrude claim, N of Helen claim: contains one of highest grade orebodies in area with ore in relatively thin-bedded sandstone about 30 ft. above carbonaceous shale; carnotite evenly disseminated in 1 to 2-ft. massive sandstone bed overlying a more thinly bedded sandstone that is highly radioactive but only lightly stained with carnotite; high grade orebody is exposed for 35 ft. N and S with maximum width of 16 ft. (average, 12 ft.) and maximum observed thickness of 2 ft.; six samples from various parts of orebody showed: 0.13% eU and 0.16% U; 0.16% eU, 0.16% U, and 0.08% V; 0.19% eU and 0.23% U; 0.19% eU, 0.19% U, and 0.04% V; 0.027% eU and 0.034% U; and 0.004% eU and 0.002% U: 603.
Helen claim, adjoins and overlaps Imogene claim on north: discovery pit exposes 8 ft. of sandstone, of which upper 4.7 ft. is white with 6-inch carnotite layer at top, but entire section is radioactive; sample from SE edge of discovery pit contained 0.044% eU, 0.049% U, and 0.04% V; carnotite stains also appear on overhanging cliff 20 to 30 ft. below pit: 603.
Imogene claim, on E side of canyon: only known carnotite deposit on claim is at discovery pit where a zone 5.5 ft. thick is exposed on corner of a cliff of relatively thin-bedded sandstone that crops out for about 15 ft. W and 15 ft. N of corner; high grade carnotite ore occurs on S and W side of corner in a lense about 5 ft. long and 2 ft. thick; sample from decomposed talus block at foot of cliff contained 0.23% eU and 0.33% U, with this higher content of U over eU suggesting that much of the carnotite on claim was precipitated recently, and being substantiated by distribution of carnotite in thin bands parallel to bedding, fractures, and plant fossils; chip sample, more representative of ore available in entire deposit, contained 0.058% eU and 0.054% U: 603.
Lucy claim, N of Pictograph claim: discovery cut is a narrow adit about 6 ft. long at base of high vertical cliff of Lakota sandstone; visible carnotite is surface coating on coarse grained porous sandstone and partly localized near plant fossils; a 5-ft. sample cut across two sandstone layers contained 0.030% eU, 0.032% U, and 0.02% V: 603.
Ophelia claim, adjoins Pictograph claim: Lakota sandstone exposed in cliff near SE corner of Pictograph claim and composed of massive sandstone beds as much as 20 ft. thick in its lower 60 to 80 ft. and discovery claim is about 20 ft. below carbonaceous shale and N and a little E of cliff; carnotite occurs as stains on quartz grains in streaks as much as 2 in. thick parallel to bedding; one vertical channel sample, considered representative of all material exposed in cut, contained 0.077% eU, 0.095% U, and 0.06% V; richest exposure on claim is 70 to 100 ft. NE of discovery pit and grab sample from it contained 0.14% eU, 0.20% U, and 0.10% V: 603.
Pictograph claim, located in 1951 and extending N along W edge of NW¼ of Sec. 30 in unsectioned T. 7 S., R. 3 E.: only workings were at face of discovery pit at N end of triangular shaped mesa, where 16 individual exposures have been mapped on low cliffs at edges and other unmapped carnotite exposures occur on E edge; carnotite occurs in lenses parallel to bedding in thin-bedded sandstone; seven vertical channel samples showed a range from 0.045 to 0.26% eU and 0.040 to 0.30% U and two grab samples contained 0.070 and 1.1% eU and 0.078 and 2.0% U respectively; several favorable zones found on this claim: 603; most notable deposit showing relatively high grade material with lense extending along cliff face for about 50 ft. and reaching a maximum thickness of over 3 ft.: 560.
Edgemont area: in Lakota sandstone: 53.
Red Canyon, 1½ mi. E of Craven Canyon: carnotite in Lakota formation in deposits reported to be more persistent and more heavily mineralized than the known deposits in Craven Canyon; small tonnage of high grade ore to be shipped from surface workings: 560.
Uranium Exploration—
Edgemont: Minerals Engineering Co. under contract to diamond drill a maximum of 50,000 ft. for U.S.A.E.C. using four drills: 629.

Suggestions to Prospectors: all carnotite exposures should be examined with Geiger counters or scintillometers, especially exposures of thin-bedded sandstone within 30 ft. above and 70 ft. below the carbonaceous shale: 603; all benches between massive sandstone beds should be examined with Geiger counters or scintillometers and trenches dug in areas of high count: 603; all exposed high grade orebodies should be mined out to get the trend of the deposits: 603; all exposures containing carnotite parallel to bedding should be prospected by blasting: 603; carbonaceous shale may serve as an ore guide since favorable zones for carnotite appear to lie 20–30 ft. above the shale or at three levels below it at 25–30 ft., 45–50 ft., and 65–70 ft. respectively: 603; carnotite-bearing rock mined during prospecting should be sorted to obtain ore containing 0.1% or more uranium in order to determine the percentage of salable ore mineable from each deposit: 603; many carnotite-bearing samples are out of equilibrium indicating that higher grade ore may be found underground beyond areas of surface leaching: 603.

Uranium Occurrences—

Coal Canyon, 4 mi. NW of Craven Canyon: carnotite in Lakota formation; material of probable ore grade averaging about one foot thick crops out on two sides of a pointed spur or bench, indicating a fair tonnage of ore there although much prospecting remains to be done; ratio of U_3O_8 to V_2O_5 in carnotite may be about 1 to 2: 560.

Craven Canyon, 8 mi. N of Edgemont: carnotite as yellow fillings between sand grains, joint fillings, and as thin coatings at three horizons within lower 150 ft. of the Lakota formation in deposits roughly parallel to the bedding or parallel to the long axes of broad lenses of thin-bedded sandstone, and similar to the uranium occurrences of the Colorado Plateau; ratio of U_3O_8 to V_2O_5 in carnotite is about 2 to 1: 560; carnotite deposits in Lakota sandstone first discovered in 1951: 603; accessibility of carnotite: 603; description of individual carnotite prospects: 603; general geology: carnotite prospects in Lakota sandstone overlain by Fuson shale on higher ridges and underlain by Morrison formation exposed in valleys; beds consist of uniformly fine grained quartz and appreciable amounts of interstitial white clay; carnotite and limonite stains abundant on sandstone throughout area and manganese oxides coat fractures and occur as spots in carnotite-bearing sandstone; unidentified dark to olive green stain coats sandstone near carnotite and chemical tests show presence of uranium and vanadium: 603; localization of carnotite deposits in lower 100 to 150 ft. of Lakota sandstone in three favorable zones: 603; location of carnotite prospects: 603; mineralogy: 603; ore deposits: 603; size and shape of carnotite deposits: 603; suggestions for prospecting on carnotite claims: 603.

Alice claim, adjoins Clara and Joan claims and is across canyon to west of Eunice claim: discovery pit exposes 3 to 5 ft. vertical thickness of carnotite ore that can be traced for about 40 ft. from the strike and may extend further; no samples taken but ore may be equivalent in grade to that in Dagmar claim of which the occurrence is almost a duplicate: 603.

Dagmar claim, adjoins NE side of Betty claim and is across canyon N of Eunice claim: discovery pit, 5 ft. deep at S corner of claim; carnotite at discovery pit and in float blocks with half-inch thick stringers of carnotite ore parallel to bedding and on steeply dipping joints and fractures, and disseminated throughout ore zone; channel sample of carnotite-bearing gray sandstone contained 0.062% eU and 0.039% U: 603.

Eggshell claim, adjoins Ophelia claim on north: carnotite occurs near fracture zone where two claims adjoin or overlap in two lenses about 20 to 25 ft. below carbonaceous shale; ore in one lense estimated to be of higher grade than that of sample from Ophelia claim which contained 0.14% eU, 0.20% U, and 0.10% V: 603.

Eunice claim, between Imogene and Lucy claims: discovery pit located about 400 ft. NW of Imogene discovery pit and at base of 50 ft. cliff of massive sandstone about 35 ft. above base of Lakota sandstone; carnotite present at discovery pit, also in high grade streaks as much as 0.05 ft. thick parallel to bedding and as disseminated blebs and stains scattered throughout massive sandstone; one vertical channel sample contained 0.024% eU and 0.015% U: 603.

Flora claim, adjoins Gertrude claim: carnotite stains visible about 20 ft. above papery-weathering, carbonaceous shale horizon and about 10 ft. below another thin carbonaceous shale, and may be the continuation of carnotite zone on Gertrude claim; second zone about 15–20 ft. above non-papery carbonaceous shale; carnotite-bearing talus blocks common below the cliff; no careful inspection or sampling carried out: 603.

Gertrude claim, N of Helen claim: contains one of highest grade orebodies in area with ore in relatively thin-bedded sandstone about 30 ft. above carbonaceous shale; carnotite evenly disseminated in a 1 to 2 ft. massive sandstone bed overlying a more thinly bedded sandstone that is highly radioactive but only lightly stained with carnotite; high grade orebody is exposed for 35 ft. N and S with maximum width of 16 ft. (average, 12 ft.) and maximum observed

SOUTH DAKOTA (contd.)
thickness of 2 ft.; six samples from various parts of orebody showed: 0.13% eU and 0.16% U; 0.16% eU, 0.16% U, and 0.08% V; 0.19% eU and 0.23% U; 0.19% eU, 0.19% U, and 0.04% V; 0.027% eU and 0.034% U; and 0.004% eU and 0.002% U: 603.
Helen claim, adjoins and overlaps Imogene claim on north: discovery pit exposes 8 ft. of sandstone, of which upper 4.7 ft. is white with 6-inch carnotite layer at top, but entire section is radioactive; sample from SE edge of discovery pit contained 0.044% eU, 0.049% U, and 0.04% V; carnotite stains also appear on overhanging cliff 20 to 30 ft. below pit: 603.
Imogene claim, on E side of canyon: only known carnotite deposit on claim is at discovery pit where a zone 5.5 ft. thick is exposed on corner of a cliff of relatively thin-bedded sandstone that crops out for about 15 ft. W and 15 ft. N of corner; high grade carnotite ore occurs on S and W side of corner in a lense about 5 ft. long and 2 ft. thick; sample from decomposed talus block at foot of cliff contained 0.23% eU and 0.33% U, with this higher content of U over eU suggesting that much of the carnotite on claim was precipitated recently, and being substantiated by distribution of carnotite in thin bands parallel to bedding, fractures, and plant fossils; chip sample, more representative of ore available in entire deposit, contained 0.058% eU and 0.054% U: 603.
Lucy claim, N of Pictograph claim: discovery cut is a narrow adit about 6 ft. long at base of high vertical cliff of Lakota sandstone; visible carnotite is surface coating on coarse grained porous sandstone and partly localized near plant fossils; a 5 ft. sample cut across two sandstone layers contained 0.030% eU, 0.032% U, and 0.02% V: 603.
Ophelia claim, adjoins Pictograph claim: Lakota sandstone exposed in cliff near SE corner of Pictograph claim and composed of massive sandstone beds as much as 20 ft. thick in its lower 60 to 80 ft. and discovery claim is about 20 ft. below carbonaceous shale and N and a little E of cliff; carnotite occurs as stains on quartz grains in streaks as much as 2 in. thick parallel to bedding; one vertical channel sample, considered representative of all material exposed in cut, contained 0.077% eU, 0.095% U, and 0.06% V; richest exposure on claim is 70 to 100 ft. NE of discovery pit and grab sample from it contained 0.14% eU, 0.20% U, and 0.10% V: 603.
Pictograph claim, located in 1951 and extending N along W edge of NW¼ of Sec. 30 in unsectioned T. 7 S., R. 3 E.: only workings were at face of discovery pit at N end of triangular shaped mesa, where 16 individual exposures have been mapped on low cliffs at edges and other unmapped carnotite exposures occur on E edge; carnotite occurs in lenses parallel to bedding in thin-bedded sandstone; seven vertical channel samples showed a range from 0.045 to 0.26% eU and 0.040 to 0.30% U and two grab samples contained 0.070 and 1.1% eU and 0.078 and 2.0% U respectively; several favorable zones found on this claim: 603; most notable deposit showing relatively high grade material with lense extending along cliff face for about 50 ft. and reaching a maximum thickness of over 3 ft.: 560.
Edgemont area: carnotite in Lakota sandstone: 53.
Red Canyon, 1½ mi. E of Craven Canyon: carnotite in Lakota formation in deposits reported to be more persistent and more heavily mineralized than the known deposits in Craven Canyon; small tonnage of high grade ore to be shipped from surface workings: 560.
Uranium Ore Guides—
Geologic Guides—
Carbonaceous shale may serve as an ore guide since favorable zones for carnotite appear to lie 20–30 ft. above the shale or at three levels below it at 25–30 ft., 45–50 ft., and 65–70 ft. respectively: Craven Canyon: 603.
Gummite Occurrences
See under individual county names and under Index III, Gummite Occurrences—South Dakota: 576.
Lawrence County
Autunite Occurrences—
Black Hills—
Annie Creek W of Portland: in porphyries (phonolite): 621.
Bald Mountain Mining District—
Annie Creek area near Trojan: autunite as fracture coatings and disseminations in siltstone of the Deadwood formation of Cambrian age and concentrated in lower two ft. of siltstone at contact with intrusive rhyolite porphyry, with purple fluorite and limonite as gangue minerals: 617; origin: 617; radiometric analyses of five samples: 617.
Bald Mountain: pitchblende with uranium mica (probably autunite): 614.
Ross Hannibal mine SE of Terry: in blue siliceous gold ore of Lower Cambrian age: 621.
Monazite Occurrences—
Tinton: monazite, 6 lbs. per ton: 11.
Pitchblende Occurrences—
Black Hills—
Bald Mountain: with uranium mica (probably autunite): 614.
Thorium Occurrences—
Tinton: monazite, 6 lbs. per ton: 11.
Torbernite Occurrences—
Black Hills—
Ross Hannibal mine SE of Terry: 82.

Uraninite Occurrences—
Black Hills—
Bald Mountain: 7, 621.
Ross Hannibal mine in Ruby Basin: 104.
Uranium Occurrences—
Black Hills—
Black Hills, northern part: uranocircite as an accessory mineral in siliceous gold ores; location not named: 621.
Annie Creek W of Portland: autunite in porphyries (phonolite): 621.
Bald Mountain Mining District—
Annie Creek near Carbonate: uranium: 617.
Annie Creek area near Trojan: autunite as fracture coating and disseminations in siltstone of Deadwood formation of Cambrian age and concentrated in lower two ft. of siltstone at contact with intrusive rhyolite porphyry, with purple fluorite and limonite as gangue minerals: 617; property located in 1890 for gold and silver on patented ground believed owned by Annie Creek Mining Co., but relocated for uranium in 1952; 617; geology: 617; mineralogy: 617; mine workings include a partly caved adit, a 10-ft. winze, dump, several prospect pits: 617; origin of autunite: uranium introduced into siltstone by hydrothermal solutions moving along contact of siltstone and underlying porphyry, with fractured siltstone forming the permeable zone for migration of solutions which were probably related to late stage of hydrothermal activity accompanying intrusion of the porphyries: 617; radiometric analyses of 5 autunite samples gave .008, .012, .030, .037, and .059% eU while chemical analyses for the same samples gave .004, .004, .020, .016, and .048% U: 617.
Bald Mountain: pitchblende and uranium mica (probably autunite): 614; uraninite: 7, 621; mineralogy of deposit: 7.
Davier mine on Anna Creek near Portland: uranium: 617; uranium intimately associated with porphyry: 602.
Ross Hannibal mine SE of Terry: torbernite: 82; autunite in blue siliceous gold ore of Lower Cambrian age: 621.
Ross Hannibal mine in Ruby Basin: uraninite: 104.
Ross Hannibal mine, Whitetail Gulch: uranium mica: 592.
Uranocircite Occurrences—
Black Hills, northern part: as an accessory mineral in siliceous gold ores; location not named: 621.
Lignites, Uranium-bearing
See under individual county names and under Index III, Lignites, Uranium-bearing—South Dakota: 27, 62, 261, 426, 443, 493.
Microlite Occurrences
See under individual county names and under Index III, Microlite Occurrences—South Dakota: 604.
Monazite Occurrences
See under individual county names and under Index III, Thorium Occurrences—South Dakota: 11, 567, 568, 570, 590, 602, 606, 620, 621.
Origin of Autunite Occurrences
See under individual county names and under Index III, Origin—Autunite Occurrences—South Dakota: 617.
Origin of Uranium Occurrences
See under individual county names and under Index III, Origin—Uranium Occurrences—South Dakota: 261, 426, 617.
Origin of Uranium-bearing Lignites
See under individual county names and under Index III, Origin—Lignites, Uranium-bearing—South Dakota: 261, 426.
Pennington County
Autunite Occurrences—
Black Hills—
General: mineralogical description: 621.
Black Hills near Keystone: 78.
Bob Ingersoll mine near Keystone: in pegmatite dikes as a thin bright yellow coating on flakes and crystals of muscovite and as seamlets in their cleavage planes: 621.
Everly claim near Keystone: in pegmatite dikes as a thin bright yellow coating on muscovite flakes and crystals and as seamlets in their cleavage planes: 621.
Harney Peak: in pegmatites: 621.
Keystone District—
Etta mine on Etta Knob near Keystone: with monazite: 568; associated with monazite in tin deposits in pegmatites: 602; with monazite, torbernite, and uraninite in pegmatites: 606; in pegmatite dikes as a thin bright yellow coating on flakes and crystals of muscovite and as seamlets in their cleavage planes: 621.
Keystone: 82; with torbernite in pegmatites: 621.
Peerless claim near Keystone: in pegmatite dikes as a thin bright yellow coating on flakes and crystals of muscovite and as seamlets in their cleavage planes: 621.
Gummite Occurrences—
Black Hills—
Ingersoll claim: some alteration of uraninite to gummite and uranophane: 576.
Microlite Occurrences—
Black Hills—
Keystone District—
Ingersoll Dike No. 1 of Bob Ingersoll mine: microlite, less than 5%, reported in core in pegmatite: 604.
Monazite Occurrences—
Black Hills—
Keystone District—
Etta mine on Etta Knob near Keystone: 590; with autunite: 568; associated with autunite in tin deposits in pegmatites: 602; with autunite, torbernite, and uraninite in pegmatites: 606.

SOUTH DAKOTA (contd.)
Newtons Fork: in placers: 621.
Spring Creek: in placers: 621.
Pitchblende Occurrences—
Rochford on Charles Swanson land: samples analyzed by eastern chemists: 622.
Thorium Occurrences—
Black Hills—
Harney Peak: in granite: 569.
Ingersoll claim: uraninite with some alteration to gummite and uranophane: 576; analyses gave UO_3, 28.582%, UO_2, 48.87%, and ThO_2, 2.15%: 576; geological age determinations by lead-uranium-thorium method gave 66.898% U, 15.243% Pb, and 1.889% Th or an age of 1667 million years: 576; mineralogy: 576.
Keystone District—
Etta mine on Etta Knob near Keystone: autunite, monazite reported: 568; autunite and monazite associated with tin deposits in pegmatites: 602; autunite, torbernite, uraninite, monazite in pegmatites: 606; monazite: 590; commercial deposits of other minerals: 568; geology: 568; ownership and mining work: 568, 596.
Newtons Fork: monazite in placers: 621.
Spring Creek: monazite in placers: 621.
Torbernite Occurrences—
Black Hills—
General: mineralogical description: 621.
Keystone District—
Etta mine on Etta Knob near Keystone: with autunite, monazite, and uraninite in pegmatites: 606.
Keystone: 78, 82; with autunite in pegmatites: 621.
Poisoned Ox claim, a copper prospect near Pactola: green uranium mica, probably torbernite: 621.
Uraninite Occurrences—
Black Hills—
Bob Ingersoll mine near Keystone: 616.
Harney Peak: 616.
Ingersoll claim: uraninite with some alteration to gummite and uranophane: 576; analyses gave UO_3, 28.582%, UO_2, 48.87%, and ThO_2, 2.15%: 576; geological age determinations by lead-uranium-thorium method gave 66.898% U, 15.243% Pb, and 1.889% Th or an age of 1667 million years: 576; mineralogy: 576.
Keystone District—
Etta mine on Etta Knob near Keystone: with autunite, monazite, and torbernite in pegmatites: 606; uraninite reported in intermediate zones in pegmatite: 604.
Ingersoll Dike No. 2 of Bob Ingersoll mine: uraninite reported as rare in intermediate zones in pegmatite: 604; in pegmatite: 70.
Peerless mine: uraninite reported in intermediate zones in pegmatite: 604.
Uranium Occurrences—
Black Hills—
Black Hills near Keystone: autunite: 78.
Black Hills, northern part: uranocircite as an accessory mineral in siliceous gold ores; location not named: 621.
Bob Ingersoll mine near Keystone: autunite as a bright yellow coating on muscovite flakes and crystals and as seamlets in their cleavage planes in pegmatite dikes: 621; uraninite: 616.
Everly claim near Keystone: autunite as a bright yellow coating on muscovite flakes and crystals and as seamlets in their cleavage planes in pegmatite dikes: 621.
Harney Peak: autunite in pegmatites: 621; pitchblende in granite: 569; uraninite in granite: 616.
Ingersoll claim: uraninite with some alteration to gummite and uranophane: 576; analyses gave UO_3, 28.582%, UO_2, 48.87%, and ThO_2, 2.15%: 576; geological age determinations by lead-uranium-thorium method gave 66.898% U, 15.243% Pb, and 1.889% Th or an age of 1667 million years: 576; mineralogy: 576.
Keystone District—
Etta mine on Etta Knob near Keystone: autunite, monazite, reported: 568; autunite and monazite associated with tin deposits in pegmatites: 602; autunite, torbernite, uraninite, monazite in pegmatites: 606; autunite as a bright yellow coating on muscovite flakes and crystals and as seamlets in their cleavage planes in pegmatite dikes: 621; uraninite reported in intermediate zones in pegmatite: 604; valuable uranium minerals in pegmatites: 596; commercial deposits of other minerals: 568; geology: 568; ownership and mining work: 568, 596.
Ingersoll Dike No. 1 of Bob Ingersoll mine: microlite, less than 5%, reported in core in pegmatite: 604.
Ingersoll Dike No. 2 of Bob Ingersoll mine: uraninite in pegmatite: 70; uraninite reported as rare in intermediate zones in pegmatite: 604.
Keystone: autunite, torbernite in pegmatites: 621; autunite, torbernite, uranocircite: 82; torbernite, uranocircite: 78.
Peerless mine: uraninite reported in intermediate zones in pegmatite: 604.
Peerless claim near Keystone: autunite as a bright yellow coating on muscovite flakes and crystals and as seamlets in their cleavage planes in pegmatite dikes: 621.
Poisoned Ox claim, a copper prospect near Pactola: green uranium mica, possibly torbernite: 621.
Poisoned Ox mine near Pactola: uranium with copper in slates: 602; zeunerite first reported here in 1897: 617.
Rochford: pitchblende found on Charles Swanson land: 622; samples analyzed by eastern chemists: 622.
Uranocircite Occurrences—
Black Hills—
Keystone: 78, 82.

Uranophane Occurrences—
Black Hills—
Black Hills, northern part: as an accessory mineral in siliceous gold ores; location not named: 621.
Ingersoll claim: some alteration of uraninite to gummite and uranophane: 576.
Zeunerite Occurrences—
Black Hills—
Poisoned Ox mine near Pactola: 617.
Pitchblende Occurrences
See under individual county names and under Index III, Pitchblende Occurrences—South Dakota: 569, 614, 622.
Radioactive Occurrences
See under individual county names and under Index III, Radioactive Occurrences—South Dakota: 628.
Thorium Occurrences
See under individual county names and under Index III, Thorium Occurrences—South Dakota: 11, 567, 568, 570, 576, 590, 602, 606, 608, 620, 621.
Torbernite Occurrences
See under individual county names and under Index III, Torbernite Occurrences—South Dakota: 78, 82, 570, 606, 620, 621.
Uraninite Occurrences
See under individual county names and under Index III, Uraninite Occurrences—South Dakota: 7, 70, 104, 570, 576, 604, 606, 616, 620, 621.
Uranium Exploration
See under individual county names and under Index III, Uranium Exploration—South Dakota: 603, 629.
Uranium Occurrences
See under individual county names and under Index III, Uranium Occurrences—South Dakota: 7, 25, 27, 53, 62, 70, 78, 82, 104, 261, 426, 443, 493, 560, 568, 569, 570, 576, 592, 596, 602, 603, 604, 606, 614, 616, 617, 620, 621, 622.
Bibliography of U.S.G.S. reports: 572.
Uranium Ore Guides
See under individual county names and under Index III, Uranium Ore Guides—South Dakota: 603.
Uranocircite Occurrences
See under individual county names and under Index III, Uranocircite Occurrences—South Dakota: 78, 82, 592, 621.
Uranophane Occurrences
See under individual county names and under Index III, Uranophane Occurrences—South Dakota: 576.
Zeunerite Occurrences
See under individual county names and under Index III, Zeunerite Occurrences—South Dakota: 617.

TEXAS

General
Radioactive Rocks—
Unnamed locality: granites: 45.
Thorium Occurrences—
General: 25
Uranium Exploration—
Trans-Pecos Region: numerous localities examined by geologic and radiometric reconnaissance surveys, car-borne scintillometer traverses, etc.: 588.
Uranium Occurrences—
General: 13, 25.
Bibliography of U.S.G.S. reports: 572.
Southwest part: uraniferous deposits in sandstone stratigraphically controlled: 443.
Trans-Pecos Region: exploration through radiometric and geologic reconnaissance surveys, car-borne scintillometer traverses, etc.: 588; geology: 588; scattered localities show small amounts of supergene uranium minerals and possibly pitchblende in one place but, in general, the area does not appear to be one where large concentrations of uranium minerals are expectable: 588.
Allanite Occurrences
See under individual county names and under Index III, Thorium Occurrences—Texas: 78, 82, 249, 594.
Autunite Occurrences
See under individual county names and under Index III, Autunite Occurrences—Texas: 589, 594.
Bibliographies
Uranium Occurrences—
Bibliography of U.S.G.S. reports: 572.
Black Shales, Uranium-bearing
See under individual county names and under Index III, Black Shales, Uranium-bearing—Texas: 426.
Burnet County
Gadolinite Occurrences—
General: 78.
Thorium Occurrences—
General: gadolinite: 78.
Cyrtolite Occurrences
See under individual county names and under Index III, Cyrtolite Occurrences—Texas: 78, 82, 594.
Ector County
Radioactive Rocks—
Well (not named): core sample of Permian limestone at 4,096 ft. depth, 0.33 ± .05 × 10^{-12} g. Ra/g. rock: 561.
El Paso County
Uranium Occurrences—
Trans-Pecos Region—
East flank of Franklin Mts.: small amounts of radioactive material in pegmatitic granite: 588; analysis of two select samples gave the following results: 0.026% eU_3O_8 and 0.004% U_3O_8 (chem.), and 0.019% eU_3O_8 and 0.009% U_3O_8 (chem.), the higher radiometric assay indicating recent leaching: 588; no uranium or thorium minerals could be identified: 588.
Fayette County
Monazite Occurrences—
Catahoula formation: monazite with heavy minerals in sand: 563.
Lower Oakeville formation: monazite with heavy minerals in sand: 563.
Upper Fayette formation: monazite with heavy minerals in sand: 563.
Thorium Occurrences—
Catahoula formation: monazite with heavy minerals in sand: 563.

TEXAS (contd.)
Lower Oakeville formation: monazite with heavy minerals in sand: 563.
Upper Fayette formation: monazite with heavy minerals in sand: 563.
Fergusonite Occurrences
See under individual county names and under Index III, Fergusonite Occurrences—Texas: 78, 82, 589, 594.
Gadolinite Occurrences
See under individual county names and under Index III, Thorium Occurrences—Texas: 78, 395, 594.
Gulf Coast
Monazite Occurrences—
Brazos River: monazite in beach sands: 565.
Colorado River: monazite in beach sands: 565.
Neches River: monazite in beach sands: 565.
San Antonio River, mouth: monazite in beach sands: 565.
Thorium Occurrences—
Brazos River: monazite in beach sands: 565.
Colorado River: monazite in beach sands: 565.
Neches River: monazite in beach sands: 565.
San Antonio River, mouth: monazite in beach sands: 565.
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Rossman prospect, 3 mi. NNE of Allamoore Post Office: visible as secondary uranium mineralization: 588.
Uranium Occurrences—
Trans-Pecos Region—
Rossman prospect, 3 mi. NNE of Allamoore Post Office: uranium mineralization in one small area of veinlets in an irregular fracture zone cutting a massive silicified limestone of the Pre-Cambrian Millican formation and with no disseminated minerals; visible secondary uranium mineralization in form of tyuyamunite and uranyl vanadate: 588; one selected chip sample taken across the veinlets gave 0.025% eU_3O_8 and 0.017% U_3O_8 (chem.), the higher radiometric assay indicating recent leaching of uranium by meteoric waters: 588; surrounding area showed no abnormal radioactivity and several other prospect pits had been filled by wash and could not be examined thoroughly: 588.
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Baringer Hill: 78, 82; in pegmatite with many other rare earth minerals: 594.
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Baringer Hill: 78, 82, 589; in pegmatite with many other rare earth minerals: 594.
Gadolinite Occurrences—
General: 395.
Baringer Hill: 78; in pegmatite with many other rare earth minerals: 594.
Gummite Occurrences—
Baringer Hill: 589; in pegmatite with many other rare earth minerals: 594.
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Baringer Hill: 78, 82, 589; in pegmatite with many other rare earth minerals: 594; mackintoshite with 45.30 ThO_2 and 22.4 UO_2 by chemical analysis; mineralogy: 580.
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Baringer Hill: 78, 82, 589; in pegmatite with many other rare earth minerals: 594.
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Baringer Hill: 78, 82, 589; in pegmatite with many other rare earth minerals: 594.
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Badu Hill, 4.5 mi. SW of Baringer Hill and 1 mi. N of Beverley: rare earth minerals in pegmatite dike, discovered in 1936 and mined for feldspar: 566.
Rare Earths, Thorium-bearing—
Baringer Hill: pegmatite with uranium and thorium in rare earth minerals discovered in 1887 and worked through 1907 for yttria: 594; rare earth minerals, many radioactive, carrying beryllium, cerium, erbium, thorium, uranium, yttrium, and other rare elements, and found in a pegmatite dike cutting Pre-Cambrian granite: 626; locality now covered by waters of Lake Buchanan, a reservoir: 626.
Rare Earths, Uranium-bearing—
Baringer Hill: pegmatite with uranium and thorium in rare earth minerals discovered in 1887 and worked through 1907 for yttria: 594; rare earth minerals, many radioactive, carrying beryllium, cerium, erbium, thorium, uranium, yttrium, and other rare elements, and found in a pegmatite dike cutting Pre-Cambrian granite: 626; locality now covered by waters of Lake Buchanan, a reservoir: 626.
Rowlandite Occurrences—
Baringer Hill: in pegmatite with many other rare earth minerals: 594.
Thorium Occurrences—
General: allanite: 249; gadolinite: 395.
Baringer Hill: locality now covered by waters of Lake Buchanan, a reservoir: 626; allanite, cyrtolite, fergusonite, mackintoshite, nivenite, polycrase, thorogummite: 82; allanite, cyrtolite, fergusonite, gadolinite, mackintoshite, nivenite, polycrase, thorogummite: 78; allanite, gadolinite, cyrtolite, fergusonite sometimes with a coating of autunite, uranite (nivenite) surrounded by gummite, mackintoshite, polycrase, rowlandite, yttrialite, and other oxidation products besides autunite and gummite, in pegmatite: 594;

* Baringer Hill is now under the waters of Lake Buchanan, a reservoir.

autunite, fergusonite, gummite, mackintoshite, nivenite, polycrase, thorogummite, yttrialite: 589; mackintoshite with 45.30 ThO_2 and 22.4 UO_2 by chemical analysis; mineralogy: 580; rare earth minerals, many radioactive, carrying beryllium, cerium, erbium, thorium, uranium, yttrium, and other rare elements, and found in a pegmatite dike cutting Pre-Cambrian granite: 626; thorogummite with 41.44 ThO_2 and 22.43 UO_3 by chemical analysis; mineralogy: 580; pegmatite with rare earth minerals discovered in 1887 and worked through 1907 for yttria: 594; mineralogy: 594; sequence of mineralization: 594.
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Baringer Hill: in pegmatite with many other rare earth minerals: 594.
Uranium Occurrences—
Baringer Hill: locality now covered by waters of Lake Buchanan, a reservoir: 626; allanite, cyrtolite, fergusonite, mackintoshite, nivenite, polycrase, thorogummite: 82; allanite, cyrtolite, fergusonite, gadolinite, mackintoshite, nivenite, polycrase, thorogummite: 78; allanite, gadolinite, cyrtolite, fergusonite sometimes with a coating of autunite, uranite (nivenite) surrounded by gummite, mackintoshite, polycrase, rowlandite, yttrialite, and other oxidation products besides autunite and gummite, in pegmatite: 594; autunite, fergusonite, gummite, mackintoshite, nivenite, polycrase, thorogummite, yttrialite: 589; mackintoshite with 45.30 ThO_2 and 22.4 UO_2 by chemical analysis; mineralogy: 580; rare earth minerals, many radioactive, carrying beryllium, cerium, erbium, thorium, uranium, yttrium, and other rare elements, and found in a pegmatite dike cutting Pre-Cambrian granite: 626; thorogummite with 41.44 ThO_2 and 22.43 UO_3 by chemical analysis; mineralogy: 580; pegmatite with rare earth minerals discovered in 1887 and worked through 1907 for yttria: 594; uraninite: 7; mineralogy: 7, 594; sequence of mineralization: 594.
Yttrialite Occurrences—
Baringer Hill: 589; in pegmatite with many other rare earth minerals: 594.
Mackintoshite Occurrences
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See under individual county names and under Index III, Thorium Occurrences—Texas: 563, 565.
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Radioactive Crude Oil—
Well—Dailey No. 1 of Humble Oil Co. at Navarro Crossing produced from Cretaceous Woodbine fm.: oil sample gave 37 sp. gr. in Deg. A.P.I.; 0.101×10^{-12} curies radon/g. oil; 0.024×10^{-12} g. Ra/g. oil; and 4.2 radon:radium ratio: 561.
Well—McKinney No. 6 of Sun Oil Co. in Sun field produced from Oligocene Frio fm.: oil sample gave 45.5 sp. gr. in Deg. A.P.I.; 0.446×10^{-12} curies radon/g. oil; 0.031×10^{-12} g. Ra/g. oil; and 15.0 radon: radium ratio: 561.
Well—Olivares No. 5 of Sun Oil Co. in Sun field produced from Oligocene Frio fm.: oil sample gave 45.5 sp. gr. in Deg. A.P.I.; 0.344×10^{-12} curies radon/g. oil; 0.009×10^{-12} g. Ra/g. oil; and 38.2 radon:radium ratio: 561.
Radioactive Rocks
Well—No. 1 Dailey, Navarro Crossing: core sample of Cretaceous quartz sandstone of Woodbine fm. at 5,889–94 ft. depth, $0.19 \pm .05 \times 10^{-12}$ g. Ra/g. rock: 561; core sample of Cretaceous shale at 5,851–67 ft. depth, $1.09 \pm .15 \times 10^{-12}$ g. Ra/g. rock: 561.
Well—No. 1 C. C. Hill, Navarro Crossing: core sample of Cretaceous quartz sandstone of Woodbine fm. at 5,934–5 ft. depth, $0.22 \pm .02 \times 10^{-12}$ g. Ra/g. rock: 561; core sample of Cretaceous shale at 5,916–17 ft. depth, $1.07 \pm .10 \times 10^{-12}$ g. Ra/g. rock: 561.
Nivenite Occurrences
See under individual county names and under Index III, Nivenite Occurrences—Texas: 78, 82, 589, 594.
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Radioactive Rocks—
Well—A. McKinney No. 5, Sun field: core sample of Oligocene quartz sandstone of Frio fm. at 5,108–16 ft. depth, $1.42 \pm .10 \times 10^{-12}$ g. Ra/g. rock: 561; core sample of Oligocene clay shale at 5096–7 ft. depth, $1.15 \pm .07 \times 10^{-12}$ g. Ra/g. rock: 561.
Well—McKinney No. 6, Sun field: core sample of Oligocene clay shale at 4,649–53

TEXAS (contd.)
ft. depth, 1.09 ± .06 × 10^{-12} g. Ra/g. rock: 561; core sample of Oligocene quartz sandstone of Frio fm. at 4,657–8 ft. depth, 0.80 ± .05 × 10^{-12} g. Ra/g. rock: 561.
Well—Olivares No. 5, Sun field: core sample of Oligocene clay shale at 4,636–7 ft. depth, 1.05 ± .05 × 10^{-12} g. Ra/g. rock: 561; core sample of Oligocene quartz sandstone of Frio fm. at 4,645–50 ft. depth, 1.17 ± .06 × 10^{-12} g. Ra/g. rock: 561.
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Bibliography of U.S.G.S. reports: 572.
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Black Shales, Uranium-bearing—
Oil wells: gamma ray logs show black shales equivalent in radioactivity to type Chattanooga shale in Tennessee and its Woodford chert equivalent: 426.
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Oil wells: gamma ray logs show black shales equivalent in radioactivity to type Chattanooga shale in Tennessee and its Woodford chert equivalent: 426.
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Bibliographies—
Geobotanical Exploration: 571.
Geochemical Exploration: 571.
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Prospectors' Guides—
Bibliography: 9, 571.
Uranium: 90.
Thorium Occurrences—
General: 12, 25.
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Mississippi River channel from Cairo, Illinois, to Gulf of Mexico: 64 samples taken at intervals between the two points showed small amounts of allanite and/or monazite, usually both, in the heavy mineral separates, the amounts being classified as "Rare," "Rare in one of the two grades analyzed and absent in the other," "Present in amounts less than one per cent but fairly common," and up to 1% for allanite and up to 2% for monazite: 609.
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Geochemical Exploration
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Custer County—
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Harney Peak Region—
Harney Peak granite from area near Custer: occurs with monazite, torbernite, and uraninite in the amblygonite-type and spodumene-type pegmatitic phases of the granite and in quartz veins with torbernite: 620.
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Annie Creek W of Portland: in porphyries (phonolite): 621.
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Annie Creek area near Trojan: autunite as fracture coatings and disseminations in siltstone of the Deadwood formation of Cambrian age and concentrated in lower two ft. of siltstone at contact with intrusive rhyolite porphyry, with purple fluorite and limonite as gangue minerals: 617.
Bald Mountain: pitchblende with uranium mica (probably autunite): 614.
Ross Hannibal mine SE of Terry: in blue siliceous gold ore of Early Cambrian age: 621.
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Bob Ingersoll mine near Keystone: in pegmatite dikes as a thin bright yellow coating on flakes and crystals of muscovite and as seamlets in their cleavage planes: 621.
Everly claim near Keystone: in pegmatite dikes as a thin bright yellow coating on muscovite flakes and crystals and as seamlets in their cleavage planes: 621.
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General: hydrous uranium oxide, probably becquerelite, in lignites: 493.

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BLACK SHALES, URANIUM-BEARING
Arkansas
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Kansas
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Bourbon formation, Top of: uranium in phosphatic nodules in shales: 462.
Bourbon formation and Hushpuckney and Stark shales: uranium in phosphatic nodules: 405.
Hushpuckney and Stark shales: uranium: 462.
Oil wells: gamma ray logs show black shales equivalent in radioactivity to type Chattanooga shale in Tennessee and its Woodford chert equivalent: 426.
Pennsylvanian black shales in eastern part: uranium contained in phosphatic nodules in shale amounting to 136 g. uranium per ton of shale: 607; uranium content can be extracted during phosphate production: 607.
Pennsylvanian shales: uranium and thorium in black shales with highest content in the phosphatic nodules: 426.
Bourbon County—
Mulky coal in Cherokee fm. at an outcrop: coal bed overlain by black shale with phosphatic nodules containing 0.011% uranium oxide: 582.
Missouri
Ste. Genevieve County—
Charles Bussen quarry N of Ste. Genevieve: highly radioactive black carbonaceous shale parting between two limestone beds near top of quarry face shows radioactivity of 0.37% eU; shale phosphatic but uranium mineral unidentified; also contained vanadium in clay mineral, illite: 599; uranium in finely disseminated carbonaceous material and purple fluorite contained in the Mississippian Spergen limestone, which also encloses thin black shale beds molded into stylolitic structures and containing 0.6% uranium or more than 100 times greater than in the average shales of the Chattanooga and Pennsylvanian type; carnotite in limestone adjacent to black shale may have been leached from shale and transported by groundwater: 426.
Oklahoma
General—
Checkerboard and Fort Scott limestones: uranium in phosphatic nodules in black shales: 405.
Northeast part: uranium in Chattanooga shales; radioactivity equivalent to that of the type Chattanooga shale in Tennessee: 426.
Oil wells: gamma ray logs show black shales equivalent in radioactivity to type Chattanooga shale in Tennessee and its Woodford chert equivalent: 426.
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General: eastern and central parts: 27.

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Fall River County—
Suggestions to Prospectors: all carnotite exposures should be examined with Geiger counters or scintillometers, especially exposures of thin-bedded sandstone within 30 ft. above and 70 ft. below the carbonaceous shale: 603; all benches between massive sandstone beds should be examined with Geiger counters or scintillometers and trenches dug in areas of high count: 603; all exposed high grade orebodies should be mined out to get the trend of the deposits: 603; all exposures containing carnotite parallel to bedding should be prospected by blasting: 603; carnotite-bearing rock mined during prospecting should be sorted to obtain ore containing 0.1% or more uranium in order to determine the percentage of salable ore mineable from each deposit: 603; carbonaceous shale may serve as an ore guide since favorable zones for carnotite appear to lie 20–30 ft. above the shale or at three levels below it at 25–30 ft., 45–50 ft., and 65–70 ft. respectively: 603; many carnotite-bearing samples are out of equilibrium indicating that higher grade ore may be found underground beyond areas of surface leaching: 603.

CARNOTITE OCCURRENCES

Missouri
Ste. Genevieve County—
Charles Bussen quarry N of Ste. Genevieve: as thin film along joint surface in limestone of Spergen (Mississippian) formation: 599; uranium in finely disseminated carbonaceous material and purple fluorite contained in the Mississippian Spergen limestone which also encloses thin black shale beds molded into stylolitic structures and containing 0.6% uranium, more than 100 times greater than in the average shales of the Chattanooga and Pennsylvanian type; carnotite in limestone adjacent to black shale may have been leached from shale and transported by groundwater: 426.
Ste. Genevieve, 5½ mi. N of: 600.
South Dakota
Fall River County—
Coal Canyon, 4 mi. NW of Craven Canyon: carnotite in Lakota formation; material of probable ore grade averaging about one foot thick crops out on two sides of a pointed spur or bench, indicating a fair tonnage of ore there although much

CARNOTITE OCCURRENCES (contd.)
prospecting remains to be done; ratio of U_3O_8 to V_2O_5 in carnotite may be about 1 to 2: 560.
Craven Canyon, 8 mi. N of Edgemont: carnotite as yellow fillings between sand grains, joint fillings, and as thin coatings at three horizons within the lower 150 ft. of the Lakota formation in deposits roughly parallel to the bedding or parallel to the long axes of broad lenses of thin-bedded sandstone, and similar to the uranium occurrences of the Colorado Plateau; ratio of U_3O_8 to V_2O_5 in carnotite is about 2 to 1: 560; carnotite deposits in Lakota sandstone first discovered in 1951: 603; accessibility of carnotite prospects: 603; descriptions of individual carnotite prospects: 603; general geology: carnotite prospects in Lakota sandstone overlain by Fuson shale on higher ridges and underlain by Morrison formation exposed in valleys; beds consist of uniformly fine grained quartz and appreciable amounts of interstitial white clay; carnotite and limonite stains abundant on sandstone throughout area and manganese oxides coat fractures and occur as spots in carnotite-bearing sandstone; unidentified dark to olive green stain coats sandstone near carnotite and chemical tests show presence of uranium and vanadium: 603; localization of carnotite deposits in lower 100 to 150 ft. of Lakota sandstone in three favorable zones: 603; location of carnotite prospects: 603; mineralogy: 603; ore deposits: 603; size and shape of carnotite deposits: 603; suggestions for prospecting on carnotite claims: 603.
Alice claim, adjoins Clara and Joan claims and is across canyon to west of Eunice claim: discovery pit exposes 3 to 5 ft. vertical thickness of carnotite ore that can be traced for about 40 ft. from the strike and may extend further; no samples taken but ore may be equivalent in grade to that in Dagmar claim, of which the occurrence is almost a duplicate: 603.
Dagmar claim, adjoins NE side of Betty claim and is across canyon N of Eunice claim: discovery pit, 5 ft. deep, at S corner of claim; carnotite at discovery pit and in float blocks with half-inch thick stringers of carnotite ore parallel to bedding and on steeply dipping joints and fractures, and disseminated throughout ore zone; channel sample of carnotite-bearing gray sandstone contained 0.062% eU and 0.039% U: 603.
Eggshell claim, adjoins Ophelia claim on north: carnotite occurs near fracture zone where two claims adjoin or overlap in two lenses about 20 to 25 ft. below carbonaceous shale; ore in one lense estimated to be of higher grade than that of sample from Ophelia claim which contained 0.14% eU, 0.20% U, and 0.10% V: 603.
Eunice claim, between Lucy and Imogene claims: discovery pit located about 400 ft. NW of Imogene discovery pit and at base of 50 ft. cliff of massive sandstone about 35 ft. above base of Lakota sandstone; carnotite present at discovery pit, also in high grade streaks as much as 0.05 ft. thick parallel to bedding and as disseminated blebs and stains scattered throughout massive sandstone; one vertical channel sample contained 0.024% eU and 0.015% U: 603.
Flora claim, adjoins Gertrude claim: carnotite stains visible about 20 ft. above papery-weathering, carbonaceous shale horizon and about 10 ft. below another thin carbonaceous shale and may be continuation of carnotite zone on Gertrude claim; second zone about 15–20 ft. above non-papery carbonaceous shale; carnotite-bearing talus blocks common below the cliff; no careful inspection or sampling carried out: 603.
Gertrude claim, N of Helen claim: contains one of highest grade orebodies in area with ore in relatively thin-bedded sandstone about 30 ft. above carbonaceous shale; carnotite evenly disseminated in 1 to 2 ft. massive sandstone bed overlying a more thinly bedded sandstone that is highly radioactive but only lightly stained with carnotite; high grade orebody is exposed for 35 ft. N and S with maximum width of 16 ft. (average, 12 ft.) and maximum observed thickness of 2 ft.; six samples from various parts of orebody showed: 0.13% eU and 0.16% U; 0.16% eU, 0.16% U, and 0.08% V; 0.19% eU and 0.23% U; 0.19% eU, 0.19% U, and 0.04% V; 0.027% eU and 0.034% U; and 0.004% eU and 0.002% U: 603.
Helen claim, adjoins and overlaps Imogene claim on north: discovery pit exposes 8 ft. of sandstone, of which upper 4.7 ft. is white with 6-inch carnotite layer at top, but entire section is radioactive; sample from SE edge of discovery pit contained 0.044% eU, 0.049% U, and 0.04% V; carnotite stains also appear on overhanging cliff 20 to 30 ft. below pit: 603.
Imogene claim, on E side of canyon: only known carnotite deposit on claim is at discovery pit where a zone 5.5 ft. thick is exposed on corner of a cliff of relatively thin-bedded sandstone that crops out for about 15 ft. W and 15 ft. N of corner; high grade carnotite ore occurs on S and W side of corner in a lense about 5 ft. long and 2 ft. thick; sample from decomposed talus block at foot of cliff contained 0.23% eU and 0.33% U, with this higher content of U over eU suggesting that much of the carnotite on claim was precipitated recently, and being substantiated by distribution of carnotite in thin bands parallel to bedding, fractures, and plant fossils; chip sample, more representa-

tive of ore available in entire deposit, contained 0.058% eU and 0.054% U: 603.
Lucy claim, N of Pictograph claim: discovery cut is a narrow adit about 6 ft. long at base of high vertical cliff of Lakota sandstone; visible carnotite is surface coating on coarse-grained porous sandstone and partly localized near plant fossils; a 5 ft. sample cut across two sandstone layers contained 0.030% eU, 0.032% U, and 0.02% V: 603.
Ophelia claim, adjoins Pictograph claim: Lakota sandstone exposed in cliff near SE corner of Pictograph claim and composed of massive sandstone beds as much as 20 ft. thick in its lower 60 to 80 ft. and discovery claim is about 20 ft. below carbonaceous shale and N and a little E of cliff; carnotite occurs as stains on quartz grains in streaks as much as 2 in. thick parallel to bedding; one vertical channel sample, considered representative of all material exposed in cut, contained 0.077% eU, 0.095% U, and 0.06% V; richest exposure on claim is 70 to 100 ft. NE of discovery pit and grab sample from it contained 0.14% eU, 0.20% U, and 0.10% V: 603.
Pictograph claim, located in 1951 and extending N along W edge of NW¼ of Sec. 30 in unsectioned T. 7 S., R. 3 E.: only workings were at face of discovery pit at N end of triangular shaped mesa, where 16 individual exposures have been mapped on low cliffs at edges and other unmapped carnotite exposures occur on E edge; carnotite occurs in lenses parallel to bedding in thin-bedded sandstone; seven vertical channel samples showed a range from 0.045 to 0.26% eU and 0.040 to 0.30% U and two grab samples contained 0.070 and 1.1% eU and 0.078 and 2.0% U respectively; several favorable zones found on this claim: 603; most notable deposit showing relatively high grade material with lense extending along cliff face for about 50 ft. and reaching a maximum thickness of over 3 ft.: 560.
Edgemont area: in Lakota sandstone: 53.
Red Canyon, 1½ mi. E of Craven Canyon: carnotite in Lakota formation in deposits reported to be more persistent and more heavily mineralized than the known deposits in Craven Canyon; small tonnage of high grade ore to be shipped from surface workings: 560.

CHLOROTHORITE MINERALOGY

General
X-ray Pattern: Baringer Hill, Texas, specimen, like thorite when unheated; name intended as synonym for thorogummite: 580.

CLAYS, URANIUM-BEARING

Missouri
Franklin County—
Eliza Gelauf property about 5½ mi. SE of Gerald: meta-torbernite chiefly on spheroidal masses of "bad" clay or so-called "sore spots" in flint fire clay: 584, 599; first radioactive occurrence reported in state: 584, 599.
Gasconade County—
Owensville: meta-torbernite in flint clay from sinkhole type pit: 564; first radioactive occurrence reported in state: 564.

COALS, URANIUM-BEARING

Kansas
General—
Southeast part: deposits in Paleozoic bituminous coal stratigraphically controlled: 443.

CYRTOLITE OCCURRENCES

Texas
Llano County—
Baringer Hill: 78, 82; in pegmatite with many other rare earth minerals: 594.

D

DRILLING OPERATIONS

South Dakota
See Uranium Exploration—
South Dakota: 629.

E–F

FERGUSONITE OCCURRENCES

Texas
Llano County—
Baringer Hill: 78, 82, 589; in pegmatite with many other rare earth minerals: 594.

FLUORITE, URANIUM-BEARING

Missouri
Ste. Genevieve County—
Charles Bussen quarry N of Ste. Genevieve: uranium in finely disseminated carbonaceous material and purple fluorite contained in the Mississippian Spergen limestone, which also encloses thin black shale beds molded into stylolitic structures and containing 0.6% uranium, more than 100 times greater than in the average shales of the Chattanooga and Pennsylvanian type; carnotite in limestone adjacent to the black shale may have been leached from shale and transported by groundwater: 426.

G

GADOLINITE OCCURRENCES

Texas
See Thorium Occurrences—
Texas: 78, 395, 594.

GEOBOTANICAL EXPLORATION

General
Bibliographies—
Bibliography: 571.
Bibliography of U.S.G.S. reports: 572.
United States
General—
Bibliography: 571.
Bibliography of U.S.G.S. reports: 572.

GEOCHEMICAL EXPLORATION

General
Bibliographies—
Bibliography: 571.
Bibliography of U.S.G.S. reports: 572.
United States
General—
Bibliography: 571.
Bibliography of U.S.G.S. reports: 572.

GEOCHEMISTRY

General
Bibliographies—
Bibliography: 571.
Bibliography of U.S.G.S. reports: 572.

GEOPHYSICAL EXPLORATION

General
Bibliographies—
Bibliography: 571.
Bibliography of U.S.G.S. reports: 572.

GEOPHYSICAL EXPLORATION (AIRBORNE)

General
Bibliographies—
Bibliography: 571.
Bibliography of U.S.G.S. reports: 572.
United States
General—
Bibliography: 571.
Bibliography of U.S.G.S. reports: 572.

GEOPHYSICAL EXPLORATION (GROUND)

General
Bibliographies—
Bibliography: 571.
Bibliography of U.S.G.S. reports: 572.
Kansas
Cherokee County—
Tri-State District: Geiger-Mueller Counter surveys: traverses made above both mined and unmined areas in the lead-zinc district: 578; radioactivity traverses showed no relation to underlying structure: 578; proved of no value in location of orebodies or delineating major structural features in this area: 578.
United States
General—
Bibliography: 571.
Bibliography of U.S.G.S. reports: 572.

GUMMITE OCCURRENCES

South Dakota
Pennington County—
Black Hills—
Ingersoll claim: some alteration of uraninite to gummite and uranophane: 576.
Texas
Llano County—
Baringer Hill: 589; in pegmatite with many other rare earth minerals: 594.

H–L

LIGNITES, URANIUM-BEARING

North Dakota
General—
General: 27, 62; uranium mineral, probably becquerelite: 493.
Southwest part: uranium in Paleocene and Eocene lignites with greatest concentrations in first group of beds below the Paleocene-Eocene unconformity: 426; uranium content of lignite beds varies but some contain slightly more than 0.01%: 426; deposits stratigraphically controlled: 443; origin of uranium in Paleocene and Eocene lignites may be by leaching from volcanic ash in White River formation and introduction into the lignite by surface waters in post-Paleocene time but the even distribution of uranium in lignite, as shown by autoradiograph of one North Dakota specimen, and the absence of apparent concentration of uranium in fracture planes in area suggest uranium was present before coalification: 426.
South Dakota
General—
General: 27, 62; uranium mineral, probably becquerelite: 493.
Northwest part: uranium in Paleocene and Eocene lignites with greatest concentrations in first group of beds below the Paleocene-Eocene unconformity: 426; uranium content of lignite beds varies but some contain slightly more than 0.01%: 426; deposits stratigraphically controlled: 443; origin of uranium in Paleocene and Eocene lignites may be by leaching from volcanic ash in White River formation and introduction into the lignite by surface waters in post-Paleocene time, but the even distribution of uranium in lignite, as shown by autoradiograph of one North Dakota specimen, and the absence of apparent concentration of uranium on fracture planes in area suggest uranium was present before coalification: 426.
Origin of uranium deposits: probably due to downward migration from radioactive tuffs in overlying Oligocene White River formation and Arikaree formation of Miocene age: 261.
United States
General: 27; Idaho, New Mexico, North Dakota, South Dakota, Wyoming: 62; Tertiary lignites in Great Plains: 63.

LIMESTONES, RADIUM-BEARING

Kansas
Butler County—
North Augusta oil field in southeast part: radium- and hydrocarbon-bearing Ordovician and Pennsylvanian dolomites and limestones: 426.

LIMESTONES, URANIUM-BEARING

Missouri
General—
General: 27.
Southeast part: deposits in Mississippian Spergen limestone stratigraphically controlled: 443.
Ste. Genevieve County—
Charles Bussen quarry N of Ste. Genevieve: uranium in finely disseminated carbonaceous material and purple fluorite contained in the Mississippian Spergen

limestone, which also encloses thin black shale beds molded into stylolitic structures and containing 0.6% uranium, more than 100 times greater than in the average shales of the Chattanooga and Pennsylvanian type; carnotite in the limestone adjacent to black shale may have been leached from shale and transported by groundwater: 426.
Ste. Genevieve, 5½ mi. N of: carnotite: 600.
United States
General: 27.

M

MACKINTOSHITE MINERALOGY

General
Chemical Analyses: Baringer Hill, Texas, specimen: 580.
X-ray pattern: Baringer Hill, Texas, specimen, like thorite when unheated: 580.

MACKINTOSHITE OCCURRENCES

Texas
Llano County—
Baringer Hill: 78, 82, 589; in pegmatite with many other rare earth minerals: 594; mackintoshite with 45.30 ThO_2 and 22.4 UO_2 by chemical analysis; mineralogy: 580.

META-TORBERNITE OCCURRENCES

Missouri
Franklin County—
Eliza Gelauf property about 5½ mi. SE of Gerald: chiefly on spheroidal masses of "bad" clay or so-called "sore spots" in flint fire clay: 584, 599; first radioactive occurrence reported in state: 584, 599.
Gasconade County—
Owensville: in flint fire clay from sinkhole type pit: 564; first radioactive occurrence reported in state: 564.

MICROLITE OCCURRENCES

South Dakota
Custer County—
Black Hills—
Custer District—
Tin Mountain mine: microlite reported in very small quantities in pegmatite: 604.
Pennington County—
Black Hills—
Keystone District—
Ingersoll Dike No. 1 of Bob Ingersoll mine: microlite, less than 5%, reported in core in pegmatite: 604.

MINERALOGY

General
Bibliographies—
Bibliography: 571.
Bibliography of U.S.G.S. reports: 572.

MONAZITE OCCURRENCES

Arkansas
See Thorium Occurrences—Arkansas: 579, 591, 609.
Iowa
See Thorium Occurrences—Iowa: 593.
Louisiana
See Thorium Occurrences—Louisiana: 577, 579, 609, 619.
Mississippi River
See Thorium Occurrences—Mississippi River: 609.
Missouri
See Thorium Occurrences—Missouri: 609.
Nebraska
See Thorium Occurrences—Nebraska: 11.
South Dakota
See Thorium Occurrences—South Dakota: 11, 567, 568, 570, 590, 602, 606, 620, 621.
Texas
See Thorium Occurrences—Texas: 563, 565.
United States
See Thorium Occurrences—United States: 609.

N

NIVENITE OCCURRENCES

Texas
Llano County—
Baringer Hill: 78, 82, 589; in pegmatite with many other rare earth minerals: 594.

O

ORIGIN

Autunite Occurrences
South Dakota—
Annie Creek area near Trojan: origin of autunite: uranium introduced into siltstone by hydrothermal solutions moving along contact of siltstone and overlying porphyry with the fractured siltstone forming the permeable zone for migration of solutions, which were probably related to late stage of hydrothermal activity accompanying intrusion of the porphyries: 617.
Carnotite Occurrences
Missouri—
Origin of carnotite in limestone adjacent to black shale in Charles Bussen quarry: may have been leached from shale and transported by groundwater: 426.
Lignites, Uranium-bearing
North Dakota—
Origin of uranium in Paleocene and Eocene lignites: may be by leaching from volcanic ash in White River formation and introduction into the lignite by surface waters in post-Paleocene time, but the even distribution of uranium in lignite, as shown by autoradiograph of one North Dakota specimen, and the absence of apparent concentration of uranium on fracture planes in area suggest uranium was present before coalification: 426.
South Dakota—
Origin of uranium in Paleocene and Eocene lignites: may be by leaching from volcanic ash in White River formation and introduction into the lignite by surface waters in post-Paleocene time but the even distribution of uranium in lignite, as shown by autoradiograph of one North Dakota specimen, and the absence of apparent concentration of uranium on frac-

ORIGIN (contd.)
ture planes in area suggest uranium was present before coalification: 426.
Origin: uranium deposited in lignites, probably by downward migration from radioactive tuffs in overlying Oligocene White River formation and Arikaree formation of Miocene age: 261.
Uranium Occurrences
Kansas—
Oil and Gas fields in southeast part: uranium believed to be present in greater-than-normal amounts in subsurface rocks because of abnormally high concentrations of radium in precipitates and drill samples, concentration of radium in comparatively small areas, and presence of helium, probably of radiogenic origin, in oil and gas fields where radium-bearing precipitates were formed: 582; presence, in altered limestones, of minerals, probably formed as a result of introduction of hydrothermal solutions, suggests localization of uranium in hydrothermal deposits, possibly of the vein type: 582; radium-bearing precipitates may have been derived from solution and redeposition from the radium-bearing rocks in the Kansas City and Arbuckle groups but absence of uranium and radium in equilibrium quantities in these rocks may indicate that uranium was removed from them or radium was introduced into them within the past thousand years; vuggy nature of rock fragments in drill samples suggests that uranium was leached from the rocks only recently, possibly by the drilling fluids when wells were drilled: 582.
Missouri—
Carnotite Occurrences—
Origin of carnotite in limestone adjacent to the black shale in Charles Bussen quarry: may have been leached from shale and transported by groundwater: 426.
North Dakota—
Lignites, Uranium-bearing—
Origin of uranium in Paleocene and Eocene lignites: may be by leaching from volcanic ash in White River formation and introduction into the lignite by surface waters in post-Paleocene time but the even distribution of uranium in lignite, as shown by autoradiograph of one North Dakota specimen, and the absence of apparent concentration of uranium on fracture planes in area suggest uranium was present before coalification: 426.
South Dakota—
Autunite Occurrences—
Annie Creek area near Trojan: origin of autunite: uranium introduced into siltstone by hydrothermal solutions moving along contact of siltstone and underlying porphyry with fractured siltstone forming the permeable zone for migration of solutions, which were probably related to late stage of hydrothermal activity accompanying intrusion of the porphyries: 617.
Lignites, Uranium-bearing—
Origin of uranium in Paleocene and Eocene lignites: may be by leaching from volcanic ash in White River formation and introduction into the lignite by surface waters in post-Paleocene time but the even distribution of uranium in lignite, as shown by autoradiograph of one North Dakota specimen, and the absence of apparent concentration of uranium on fracture planes in area suggest uranium was present before coalification: 426.
Origin of uranium in lignites: probably due to downward migration from radioactive tuffs in overlying Oligocene White River formation and Arikaree formation of Miocene age: 261.

P

PHOSPHORITES, URANIUM-BEARING
Kansas
General—
Bourbon formation, Top of: uranium in phosphatic nodules in shales: 462.
Hushpuckney and Stark shales: uranium: 462.
Oklahoma
General—
Pennsylvanian black shales at top of Checkerboard limestone member of Coffeyville formation and of Fort Scott (or Oswego) limestone: uranium in phosphatic nodules: 462.
Woodford chert: uranium: 462.
PITCHBLENDE OCCURRENCES
South Dakota
Lawrence County—
Black Hills—
Bald Mountain: with uranium mica (probably autunite): 614.
Pennington County—
Black Hills—
Harney Peak: in granite: 569.
Rochford on Charles Swanson land: samples analyzed by eastern chemists: 622.
POLYCRASE OCCURRENCES
Texas
Llano County—
Baringer Hill: 78, 82, 589; in pegmatite with many other rare earth minerals: 594.
PROSPECTING FOR URANIUM
See Uranium Exploration.
PROSPECTORS' GUIDES
See also: Uranium Exploration.
General
Uranium: 90.
Bibliographies
General: 9, 571.
Missouri
General—
Uranium: 599.
United States
General—
Bibliography: 9, 571.
Uranium: 90.

Uranium
General: 90.
Bibliography: 9, 571.
Missouri: 599.
United States: 90.

Q–R

RADIOACTIVE ASPHALT

Kansas
Linn County—
Sample from SE corner of county: radiometric analysis showed 0.001% eU_3O_8: 582.

RADIOACTIVE ASPHALTITE

Oklahoma
General—
West part: nodular asphaltite-like bitumen samples with abnormally high radioactivity count: 574.
West Part—
Nodular asphaltite-like bitumen samples: abnormally high radioactivity count: 574.

RADIOACTIVE COAL

Kansas
Bourbon County—
Mulky coal in Cherokee formation at an outcrop: radiometric analysis showed 0.004% eU_3O_8, the radioactivity of the coals sampled; coal bed overlain by black shale with phosphatic nodules containing 0.011% uranium oxide: 582.
Crawford County—
Bevier coal in Cherokee formation from abandoned strip pit, slacked: radiometric analysis showed 0.001% eU_3O_8: 582.
Franklin County—
Ottawa coal in Douglas formation at an outcrop: radiometric analysis showed 0.001% eU_3O_8: 582.
Osage County—
Nodaway coal in Wabaunsee formation in strip pit: radiometric analysis showed 0.001% eU_3O_8: 582.
Southeast Part—
Pennsylvanian coals in Bourbon, Crawford, Franklin, and Osage Cos.: radiometric analyses of fifteen samples showed radioactivity in only five samples ranging from 0.001–0.004% eU_3O_8: 582.

RADIOACTIVE CRUDE OIL

Oklahoma
Pontotoc County—
Well—Moore No. 1A Harper of Magnolia Petroleum Co. in Fitts pool produced from Ordovician Viola-Simpson fm.: oil sample gave 37 sp. gr. in Deg. A.P.I.; 0.143 × 10^{-12} curies radon/g. oil; 0.005 × 10^{-12} g. Ra/g. oil; and 28.6 radon:radium ratio: 561.
Well—Moore No. 1B Harper of Magnolia Petroleum Co. in Fitts pool produced from Pennsylvanian Cromwell fm.: oil sample gave 37 sp. gr. in Deg. A.P.I.; 0.049 × 10^{-12} curies radon/g. oil; 0.007 × 10^{-12} g. Ra/g. oil; and 7.0 radon:radium ratio: 561.
Well—Moore No. 7 Schauers of Magnolia Petroleum Co. in Fitts pool produced from Ordovician Viola-Simpson fm.: oil sample gave 35 sp. gr. in Deg. A.P.I.; 0.087 × 10^{-12} curies radon/g. oil; 0.019 × 10^{-12} g. Ra/g. oil; and 4.6 radon:radium ratio: 561.
Well—Moore No. 7A Schauers of Magnolia Petroleum Co. in Fitts pool produced from Pennsylvanian Cromwell fm.: oil sample gave 37 sp. gr. in Deg. A.P.I.; 0.136 × 10^{-12} curies radon/g. oil; 0.034 × 10^{-12} g. Ra/g. oil; and 4.0 radon:radium ratio: 561.

Texas
Navarro County—
Well—Dailey No. 1 of Humble Oil Co. at Navarro Crossing produced from Cretaceous Woodbine fm.: oil sample gave 37 sp. gr. in Deg. A.P.I.; 0.101 × 10^{-12} curies radon/g. oil; 0.024 × 10^{-12} g. Ra/g. oil; and 4.2 radon:radium ratio: 561.
Starr County—
Well—McKinney No. 6 of Sun Oil Co. in Sun field produced from Oligocene Frio fm.: oil sample gave 45.5 sp. gr. in Deg. A.P.I.; 0.466 × 10^{-12} curies radon/g. oil; 0.031 × 10^{-12} g. Ra/g. oil; and 15.0 radon:radium ratio: 561.
Well—Olivares No. 5 of Sun Oil Co. in Sun field produced from Oligocene Frio fm.: oil sample gave 45.5 sp. gr. in Deg. A.P.I.; 0.344 × 10^{-12} curies radon/g. oil; 0.009 × 10^{-12} g. Ra/g. oil; and 38.2 radon:radium ratio: 561.

RADIOACTIVE OCCURRENCES

Arkansas
Benton County—
Bentonville: earthy material from limestone cave found by Leib and gave photograph of outer wrappings when tied up in a box and placed before a camera in a dark room for several hours; finder advised by professor at University of Arkansas that further study would be needed to determine whether sample contained radium or any other radioactive material: 605.

Missouri
Barry County—
Radium Mine in Ozark Mountains: samples of bluish colored ore formed radiographs on photographic plates: 612; samples tested by several geologists and showed radioactivity: 612; mine on land owned by John P. Nagel (or Nagle), who began development work there: 612; consignment of ore sent to Germany for analysis: 612.
Cass County—
Cuttings from oil test well in SW¼ NE¼ Sec. 29, T. 46 N., R. 32 W.: slight radioactivity in Lower Pennsylvanian and Upper Mississippian strata: 599.
Gasconade County—
Owensville: weak radioactivity in sample with fragments of black carbonaceous material associated with flint clay: no further information available: 599.

RADIOACTIVE OCCURRENCES (contd.)
Oklahoma
General—
West part: nodular asphaltite-like bitumen samples with abnormally high radioactivity count: 574.
West Part—
Nodular asphaltite-like bitumen samples: abnormally high radioactivity count: 574.
South Dakota
Butte County—
Area between South Dakota and Wyoming border near Belle Fourche: radioactive rock, possibly uranium-bearing: 628; some ore samples collected by Homestake Mining Co. at Lead, South Dakota: 628; negotiations for leases and exploratory drilling rights underway: 628.

RADIOACTIVE OIL WELLS
Kansas
Butler County—
Augusta field: over 100 radioactive oil wells reported: 582. (See Index II, Kansas-Butler Co.-Radioactive Oil Wells, for detailed listings of individual well names.): 582.
Beadles well in Arbuckle formation: precipitates contaminated with surface debris showed 0.002% eU_3O_8 and 0.001% U_3O_8: 582.
Bush well of Morrison Oil Co. in Arbuckle formation: reports on two samples: precipitates collected from pipes or tanks showed 0.12% eU_3O_8 and 0.000% U_3O_8; brines showed 0.09 mg. U_3O_8/liter: 582.
Darter (?) well: precipitates collected from pipes or tanks showed 0.21% eU_3O_8 and 0.001% U_3O_8: 582.
Hawk well in Kansas City and Hunton formations: precipitates contaminated with surface debris showed 0.001% eU_3O_8 and 0.002% U_3O_8: 582.
Klinger well in Kansas City formation: brines showed 0.04 mg. U_3O_8/liter: 582.
Klinger No. 1 well in Simpson formation: precipitates collected from pipes or tanks showed 0.070% eU_3O_8 and 0.000% U_3O_8: 582.
Liggett No. 6 well of Sohio Petroleum Co. in Cherokee (Bartlesville) formation: precipitates collected from pipes or tanks showed 0.002% eU_3O_8 and 0.000% U_3O_8: 582.
Liggett No. S-1 well of Sohio Petroleum Co. in Douglas formation: precipitates collected from pipes or tanks showed 0.001% eU_3O_8 and 0.000% U_3O_8: 582.
McLaughlin No. 1 well in Kansas City formation: precipitates collected from pipes or tanks showed 0.22% eU_3O_8 and 0.001% U_3O_8: 582.
Robinson No. 1 well of Deep Rock Oil Co. in Viola formation: precipitates collected from pipes or tanks showed 1.33% eU_3O_8 and 0.000% U_3O_8: 582.
Starkey well in Arbuckle (?) formation: reports on two samples: precipitates contaminated with surface debris showed 0.004% and 0.085% eU_3O_8 and 0.003% and 0.000% U_3O_8: 582.
Stern No. 1 well in Viola formation: precipitates collected from pipes or tanks showed 0.002% eU_3O_8 and 0.000% U_3O_8: 582.
Young No. 4A well in Mississippian formation: precipitates collected from pipes or tanks showed 0.32% eU_3O_8 and 0.000% U_3O_8: 582.
Cowley County—
Bauman well in Simpson formation: brines showed 0.05 mg. U_3O_8/liter: 582.
Bower well of Continental Oil Co. in Arbuckle and Kansas City formations: reports on four samples: precipitates collected from pipes or tanks showed 0.048%, 5.16%, and 8.15% eU_3O_8 and 0.001%, 0.001%, and 0.000% U_3O_8; precipitates contaminated with surface debris showed 0.32% eU_3O_8 and 0.001% U_3O_8: 582.
Bower or Graham well of Continental Oil Co.: precipitates collected from pipes or tanks showed 10.85% eU_3O_8 and 0.001% U_3O_8: 582.
Boyd well in Cherokee (Bartlesville) formation: precipitates contaminated with surface debris showed 0.040% eU_3O_8 and 0.001% U_3O_8: 582.
Dilworth Fee No. 2 well of Dilworth and Miller in Mississippian formation: reports on two samples: precipitates collected from pipes or tanks showed 0.24% and 0.48% eU_3O_8 and 0.005% and 0.002% U_3O_8: 582.
Finch well of Hill Oil Co. in Kansas City and Cherokee (Bartlesville) formations: precipitates contaminated with surface debris showed 0.002% eU_3O_8 and 0.002% U_3O_8: 582.
Lewis well in Arbuckle formation: precipitates collected from pipes or tanks showed 0.001% eU_3O_8 and 0.001% U_3O_8: 582.
Radcliffe well: reports on two samples: precipitates contaminated with surface debris showed 0.001% and 0.019% eU_3O_8 and 0.000% and 0.001% U_3O_8: 582.
Weathered well of Bennett and others in Arbuckle formation: reports on two samples: precipitates contaminated with surface debris showed 0.027% and 0.085% eU_3O_8 and 0.001% and 0.000% U_3O_8: 582.
Marion County—
Bevins No. 4 well in Mississippian formation: precipitates collected from pipes or tanks showed 0.022% eU_3O_8 and 0.000% U_3O_8: 582.
Greeley well in Viola formation: precipitates collected from pipes or tanks showed 0.013% eU_3O_8 and 0.001% U_3O_8: 582.
Joliffe well of Faylor (?) Co. in Viola formation: precipitates contaminated with surface debris showed 0.048% eU_3O_8 and 0.001% U_3O_8: 582.
Joliffe (?) well: reports on two samples, Serial Nos. 3660 and 18375: precipitates collected from pipes or tanks showed 0.27% eU_3O_8 and 0.001% U_3O_8; precipitates contaminated with surface

debris showed 0.083% eU_3O_8 and 0.003% U_3O_8: 582.
Joliffe (?) well (different location): reports on five samples, Serial Nos. 3661, 3663, 5799, 5802, and 5808: precipitates contaminated with surface debris showed 0.023%, 0.059%, 0.103%, 0.20%, and 0.55% eU_3O_8; and no listing, 0.003%, 0.001%, 0.000%, and 0.001% U_3O_8: 582.
Reamy well of the Cooperative Refinery Association in Kansas City and Viola formations: precipitates contaminated with surface debris showed 0.002% eU_3O_8 and 0.001% U_3O_8: 582.
Spier (?) well: precipitates contaminated with surface debris showed 0.088% and 0.10% eU_3O_8 and 0.003% and 0.000% U_3O_8: 582.
Spier No. 1 well of C. R. Colpitt in Mississippian formation: reports on five samples: precipitates collected from pipes or tanks showed 0.92% eU_3O_8 and 0.001% U_3O_8; precipitates contaminated with surface debris showed 0.077%, 0.088%, 0.091%, and 0.63% eU_3O_8 and 0.001%, 0.003%, 0.001%, and 0.000% U_3O_8: 582.
Spier No. 1A well of Berry and Eells: precipitates contaminated with surface debris showed 0.001% eU_3O_8 and no listing for U_3O_8: 582.

RADIOACTIVE ROCKS

Minnesota
General—
Age Determinations—
Pre-Cambrian rocks: 587.
Hennepin County—
Quarry in Minneapolis: limestone showed 0.60×10^{-12} g. Ra/g. rock: 561.
Oklahoma
Nowata County—
Well (not named): three core samples of Pennsylvanian Bartlesville sandstone, at 494 ft. depth, $0.82 \pm .06 \times 10^{-12}$ g. Ra/g. rock; at 505 ft. depth, $0.58 \pm .05 \times 10^{-12}$ g. Ra/g. rock; and at 512 ft. depth, $0.51 \pm .05 \times 10^{-12}$ g. Ra/g. rock: 561.
Pontotoc County—
Well—Moore No. 1A Harper in Fitts pool: sample of cuttings of Ordovician limestone at 4,365–73 ft. depth, $0.18 \pm .03 \times 10^{-12}$ g. Ra/g. rock: 561; sample of cuttings of Ordovician shaly limestone of Viola fm. at 3,810–35 ft. depth, $0.78 \pm .06 \times 10^{-12}$ g. Ra/g. rock: 561; sample of cuttings of Ordovician shaly limestone, sandstone of the McLish fm., at 4,245–81 ft. depth, $0.29 \pm .03 \times 10^{-12}$ g. Ra/g. rock: 561.
Well—Moore No. 7 Schauers in Fitts pool: sample of cuttings of Ordovician dolomite at 4,370–75 ft. depth, $0.29 \pm .03 \times 10^{-12}$ g. Ra/g. rock: 561; sample of cuttings of Ordovician limestone, shale, quartz of McLish fm. at 4,265–70 ft. depth, $0.31 \pm .03 \times 10^{-12}$ g. Ra/g. rock: 561; sample of cuttings of Ordovician shaly limestone of Viola fm. at 3,780–00 ft. depth, $1.30 \pm .07 \times 10^{-12}$ g. Ra/g. rock: 561; sample of cuttings of Pennsylvanian shaly sandstone of Cromwell fm. at 2,510–40 ft. depth, $0.67 \pm .05 \times 10^{-12}$ g. Ra/g. rock: 561.
Texas
General—
Unnamed locality: granites: 45.
Ector County—
Well (not named): core sample of Permian limestone at 4,096 ft. depth, $0.33 \pm .05 \times 10^{-12}$ g. Ra/g. rock: 561.
Navarro County—
Well—No. 1 C. C. Hill at Navarro Crossing: core sample of Cretaceous quartz sandstone of Woodbine fm. at 5,934-5 ft. depth, $0.22 \pm 0.02 \times 10^{-12}$ g. Ra/g. rock: 561; core sample of Cretaceous shale at 5,916-17 ft. depth, $1.07 \pm .10 \times 10^{-12}$ g. Ra/g. rock: 561.
Well—No. 1 Dailey at Navarro Crossing: core sample of Cretaceous quartz sandstone of Woodbine fm. at 5,889–94 ft. depth, $0.19 \pm .05 \times 10^{-12}$ g. Ra/g. rock: 561; core sample of Cretaceous shale at 5,851–67 ft. depth $1.09 \pm .15 \times 10^{-12}$ g. Ra/g. rock: 561.
Starr County—
Well—A. McKinney No. 5 in Sun field: core sample of Oligocene clay shale at 5096–7 ft. depth, $1.15 \pm .07 \times 10^{-12}$ g. Ra/g. rock: 561; core sample of Oligocene quartz sandstone of Frio fm. at 5,108–16 ft. depth, $1.42 \pm .10 \times 10^{-12}$ g. Ra/g. rock: 561.
Well—McKinney No. 6 in Sun field: core sample of Oligocene clay shale at 4,649–53 ft. depth, $1.09 \pm .06 \times 10^{-12}$ g. Ra/g. rock: 561; core sample of Oligocene quartz sandstone of Frio fm. at 4,657–8 ft. depth, $0.80 \pm .05 \times 10^{-12}$ g. Ra/g. rock: 561.
Well—Olivares No. 5 in Sun field: core sample of Oligocene clay shale at 4,636–7 ft. depth, $1.05 \pm .05 \times 10^{-12}$ g. Ra/g. rock: 561; core sample of Oligocene quartz sandstone of Frio fm. at 4,645–50 ft. depth, $1.17 \pm .06 \times 10^{-12}$ g. Ra/g. rock: 561.

RADIOACTIVE SOIL

*Minnesota**
Anoka County—
Coon Creek: soil, dune sand, 28 g. Ra $\times 10^{14}$, 27 g. Th $\times 10^{7}$, and 96 Th/Ra $\times 10^{-5}$: 611.
Beltrami County—
Bemidji: soil, outwashed plain from late Wisconsin drift, 25 g. Ra $\times 10^{14}$, 34 g. Th $\times 10^{7}$, 136 Th/Ra $\times 10^{-5}$: 611.
Carlton County—
Cloquet: soil, moraine from early Wisconsin drift, 13 g. Ra $\times 10^{14}$, 32 g. Th $\times 10^{7}$, 246 Th/Ra $\times 10^{-5}$: 611.
Clay County—
Manitoba Junction: soil, Red River Valley, boulder-clay, late Wisconsin drift, 62 g. Ra $\times 10^{14}$, 60 g. Th $\times 10^{7}$, 97 Th/Ra $\times 10^{-5}$: 611.
Fillmore County—
Preston: soil, loess, 64 g. Ra $\times 10^{14}$, 47 g. Th $\times 10^{7}$, 73 Th/Ra $\times 10^{-5}$: 611.

* See footnote, page 279.

RADIOACTIVE SOIL (contd.)
Hennepin County—
University Farm: soil, till coating on outwashed plain from late Wisconsin drift, 75 g. Ra × 10^{14}, 71 g. Th × 10^{7}, 95 Th/Ra × 10^{-6}: 611.
Hubbard County—
Guthrie: soil, outwashed plain from late Wisconsin drift, 27 g. Ra × 10^{14}, 25 g. Th × 10^{7}, 93 Th/Ra × 10^{-6}: 611.
Norman County—
Twin Valley: soil, sandy plain, Lake Agassiz, rich in nitrogen, 17 g. Ra × 10^{14}, 28 g. Th × 10^{7}, 165 Th/Ra × 10^{-6}: 611.
Pine County—
Nickerson: soil, sandy deposit on moraine from early Wisconsin drift, 24 g. Ra × 10^{14}, 32 g. Th × 10^{7}, 133 Th/Ra × 10^{-6}: 611.
Willow River: soil, outwashed plain from early Wisconsin drift, 20 g. Ra × 10^{14}, 32 g. Th × 10^{7}, 160 Th/Ra × 10^{-6}: 611.
Pope County—
Cyrus: soil, Red River Valley, boulder-clay, and late Wisconsin drift, 80 g. Ra × 10^{14}, 64 g. Th × 10^{7}, 80 Th/Ra × 10^{-6}: 611.
Rock County—
Luverne: soil, loess, 64 g. Ra × 10^{14}, 41 g. Th × 10^{7}, 64 Th/Ra × 10^{-6}: 611.
Todd County—
Philbrook: soil, outwashed plain from late Wisconsin drift, 20 g. Ra × 10^{14}, 29 g. Th × 10^{7}, 145 Th/Ra × 10^{-5}: 611.

RADIOACTIVE SPRING DEPOSITS
Arkansas
Garland County—
Hot Springs: tufa deposits around 44 hot springs showed slight radioactivity of about 0.003 mcg. Ra per kg. of material: 625.
Hot Springs Reservation on W slope of Hot Springs Mountain: tufa from springs, radioactivity of gases from dissolved tufa was less than one-millionth of the amount of Ra associated with an equal weight of uranium in pitchblende: 562.

RADIOACTIVE SPRINGS
Arkansas
Garland County—
Hot Springs: 44 springs within area of 3 acres with temperatures ranging from 35 to 64° C.: 625; uranium: 294; average radioactivity of 44 hot springs and 2 cold springs amounted to 0.00088 microcuries/liter or 2.37 Mache units, and ranged from 0.00002 to 0.00321 microcuries/liter and 0.05 to 8.66 Mache units in the 44 hot springs: 625; radioactivity due to presence of radium emanation since residue from evaporation of water showed no activity: 625; tufa deposits around springs showed slight radioactivity of about 0.003 mcg. Ra per kg. of material: 625.
Hot Springs Reservation on W slope of Hot Springs Mountain: radioactivity of spring waters tested: 562; observed radioactivity per liter of water ranged from 0.4 to 91.6 × 10^{-4} g. uranium in samples from 44 hot springs; and 6.0 and 18.1 × 10^{-4} g. uranium in two samples from cold springs: 562; water samples from 44 springs tested and showed gaseous, radioactive constituent properties identical with those of radium emanation: 562; methods used: 562.
Missouri
Saline County—
Sweet Springs: uranium: 294.
See also Radioactive Waters—Missouri: 598.

RADIOACTIVE SPRINGS, URANIUM-BEARING
Arkansas
Garland County—
Hot Springs: uranium in radioactive springs: 294.
Missouri
Saline County—
Sweet Springs: uranium in radioactive springs: 294.

RADIOACTIVE TUFA
Arkansas
Garland County—
Hot Springs: tufa deposits around 44 hot springs showed slight radioactivity of about 0.003 mcg. Ra per kg. of material: 625.
Hot Springs Reservation on W slope of Hot Springs Mountain: tufa from springs; radioactivity of gases from dissolved tufa was less than one-millionth of the amount of Ra associated with an equal weight of uranium in pitchblende: 562.
Hot Spring County—
Magnet Cove—
J. W. Kimzey property on Tufa Hill: samples showed 0.003–0.063% eU but radioactivity due, in part, to thorium content: 581.
S. F. Moore property at Tufa Hill: sample of siliceous tufa float showed 0.027% eU but radioactivity due, in part, to thorium content: 581.

RADIOACTIVE WATERS
Arkansas
Garland County—
Hot Springs: average radioactivity of 44 hot springs and 2 cold springs amounted to 0.00088 microcuries/liter or 2.37 Mache units, and ranged from 0.00002 to 0.00321 microcuries/liter and 0.05 to 8.66 Mache units in the 44 hot springs; radioactivity due to presence of radium emanation since residue from evaporation of water showed no activity: 625; uranium in radioactive springs: 294.
Hot Springs Reservation on W slope of Hot Springs Mountain: water samples from 44 springs tested and showed gaseous radioactive constituent properties identical with those of radium emanation; observed activity per liter of water ranged from 0.4 to 91.6 × 10^{-4} g. uranium in samples from 44 hot springs, and 6.0 and 18.1 ×

10^{-4} g. uranium in two samples from cold springs: 562.
Missouri
General—
General: methods of determination of radioactivity of spring and well waters: 598; radioactivity of deep well waters usually lower than that of spring waters: 598; radioactivity of waters and their mineral constituents showed no apparent connection: 598; types of water studied:
Alkaline: 598;
Chalybate: 598;
Muriatic or brines: 598;
Sulphatic: 598;
Sulphur: 598.
Boone County—
Columbia—
Christian College Deep Well: radioactivity, 1.7 × 10^{-4} g. uranium/liter of water: 598.
City Deep Well: radioactivity, 0.25 × 10^{-4} g. uranium/liter of water: 598.
Rollins Spring: radioactivity, 4.5 × 10^{-4} g. uranium/liter of water: 598.
University Deep Well: radioactivity, 1.5 × 10^{-4} g. uranium/liter of water: 598.
Cedar County—
Eldorado Springs—
Eldorado Deep Sulphur Well: radioactivity, 0.5 × 10^{-4} g. uranium/liter of water: 598.
Eldorado Springs: radioactivity, 1.4 × 10^{-4} g. uranium/liter of water: 598.
Clinton County—
Plattsburg—
Plattsburg Spring: radioactivity, 3.7 × 10^{-4} g. uranium/liter of water: 598.
Greene County—
Springfield—
Deep Well: radioactivity, 0.1 × 10^{-4} g. uranium/liter of water: 598.
Howard County—
Fayette—
Boons Lick Spring: radioactivity, 4.6 × 10^{-4} g. uranium/liter of water: 598.
Jackson County—
Independence—
Cusenbery Spring: radioactivity, 12.6 × 10^{-4} g. uranium/liter of water: 598.
Kansas City, 5 mi. E of—
Lake Spring: radioactivity, 48.2 × 10^{-4} g. uranium/liter of water: 598.
Johnson County—
Warrensburg—
Electric Spring: radioactivity, 2.25 × 10^{-4} g. uranium/liter of water: 598.
Pertle Spring: radioactivity, 2.9 × 10^{-4} g. uranium/liter of water: 598.
Morgan County—
Versailles—
Alum Well: radioactivity, 0.8 × 10^{-4} g. uranium/liter of water: 598.
Oregon County—
Greer—
Greer Springs: radioactivity, 0.4 × 10^{-4} g. uranium/liter of water: 598.
Saline County—
Sweet Springs: uranium in radioactive springs: 294.
Akesion Water: radioactivity, 3.4 × 10^{-4} g. uranium/liter of water: 598.
Sweet Springs: radioactivity, 23.7 × 10^{-4} g. uranium/liter of water: 598.
Vernon County—
Nevada—
The Artesian Well: radioactivity, 4.5 × 10^{-4} g. uranium/liter of water: 598.
Iron Spring: radioactivity, 2.0 × 10^{-4} g. uranium/liter of water: 598.
White Sulphur Spring: radioactivity, 2.3 × 10^{-4} g. uranium/liter of water: 598.

RADIOACTIVITY

Soils
General—
Fertile soils: higher radium and thorium emanations than less fertile soils: 611.
Methods of determination of radioactivity: Minnesota soils: 611.
Radioactive enrichment of soils: increases soil fertility and benefits vegetation: 611.

RADIOACTIVITY DETERMINATIONS

Missouri
Crawford County—
Bourbon magnetic anomaly on NE flank of Ozark Mts.: study made of Pre-Cambrian rhyolite porphyry section of well core using 40 samples ranging in depth from 1406–2081 ft.:
method of measurement of hard gamma radiation; calibration; accuracy of results: 575;
results of study showed:
1. mineral densities are related directly to iron content and increase steadily with depth;
2. radioactive content decreases directly with depth and with increases in mineral densities;
3. lower radioactivity counts for mineralized zones are not an effect of absorption but an actual decrease in radioactive content: 575;
average radioactive content of different mineral density groups:
1. mineral density range of 2.50–3.00 g./cm³ showed an average radioactive content for 15 samples in radium equivalents of grams × 10^{-12} Ra per g. was 6.52: 575;
2. mineral density range of 3.00–3.50 g./cm³ showed an average radioactive content for 16 samples in radium equivalents of grams × 10^{-12} Ra per g. was 5.44: 575;
3. mineral density range of 3.50–4.00 g./cm³ showed an average radioactive content for 6 samples in radium equivalents of grams × 10^{-12} Ra per g. was 3.08: 575;
4. mineral density range of 4.00–4.50 g./cm³ showed an average radioactive content for 3 samples in radium equivalents of grams × 10^{-12} Ra per g. was 1.90: 575;
results may serve as guides to indicate location of ore in wells since the ionization of potassium granite has been

RADIOACTIVITY DETERMINATIONS (contd.)

shown to be more than twice that for the other components taken together and, while the percentage in rhyolite porphyry is lower, probably 3 rather than 3.8, potassium should still supply more of the counts and the low activity of the mineralized zones is entirely explained by leaching out of potassium: 575.

RADIOACTIVITY STUDIES

Minnesota

General—

Pre-Cambrian rocks: 587.

RADIOACTIVITY SURVEYS

Oklahoma

Greater Seminole Area—

General: surveys made of many formations. (See Index II, Oklahoma-Greater Seminole Area-Radioactivity Surveys, for detailed listings): 597.

RADIOMETRIC ANALYSES

Asphalt

Kansas—

Linn County—

Sample from SE corner of county: radiometric analysis showed 0.001% eU_3O_8: 582.

Coal

Kansas—

Bourbon County—

Mulky coal in Cherokee fm. at an outcrop: radiometric analysis showed 0.004% eU_3O_8, the radioactivity of the coals sampled; coal bed overlain by black shale, with phosphatic nodules containing 0.011% uranium oxide: 582.

Crawford County—

Bevier coal in Cherokee fm. from abandoned strip pit, slacked: radiometric analysis showed 0.001% eU_3O_8: 582.

Franklin County—

Ottawa coal in Douglas fm. at an outcrop: radiometric analysis showed 0.001% eU_3O_8: 582.

Osage County—

Nodaway coal in Wabaunsee fm. in strip pit: radiometric analysis showed 0.001% eU_3O_8: 582.

Southeast Part—

Pennsylvanian coal in Bourbon, Crawford, Franklin, and Osage Cos.: radiometric analyses of fifteen samples showed radioactivity in only five samples ranging from 0.001–0.004% eU_3O_8: 582.

Drill Samples

Kansas—

Butler County—

Ambler No. 1 well, analysis by Hammer and Maclean Drilling Co.: range in percent eU_3O_8, 0.000–0.005: 582.

Ambler No. 2 well, analysis by Hammer and Maclean Drilling Co.: range in percent eU_3O_8, 0.002–0.006: 582.

Ambler No. 3 well, analysis by Hammer and Maclean Drilling Co.: range in percent eU_3O_8, 0.000–0.005: 582.

Ambler No. 4 well, analysis by Hammer and Maclean Drilling Co.: range in percent eU_3O_8, 0.000–0.004: 582.

Ambler No. 5 well, analysis by Hammer and Maclean Drilling Co.: range in percent eU_3O_8, 0.001–0.003: 582.

Augustine No. 1 well, analysis by Sheldon and Wixon: range in percent eU_3O_8, 0.000–0.001: 582.

Bates No. 2 well, analysis by Hammer and Maclean Drilling Co.: range in percent eU_3O_8, 0.000–0.005: 582.

Foster No. 14 well, analysis by Magnolia Petroleum Co.: range in percent eU_3O_8, 0.000–0.008: 582.

Foster No. 21 well, analysis by Magnolia Petroleum Co.: range in percent eU_3O_8, 0.000–0.005: 582.

Koogler No. 71 well, analysis by Magnolia Petroleum Co.: range in percent eU_3O_8, 0.002–0.004: 582.

Kramer No. 14 well, analysis by Magnolia Petroleum Co.: range in percent eU_3O_8, 0.001–0.006: 582.

Kramer No. 17 well, analysis by Magnolia Petroleum Co.: range in percent eU_3O_8, 0.000–0.005: 582.

Kramer No. 18 well, analysis by Magnolia Petroleum Co.: range in percent eU_3O_8, 0.000–0.006: 582.

Liggett No. W-14 well, analysis by Sohio Petroleum Co.: range in percent eU_3O_8, 0.003–0.004: 582.

Linn No. 1A well, analysis by Colpitt: range in percent eU_3O_8, 0.000–0.004: 582.

Loomis No. 1 well, analysis by Aikman and Bennetts: range in percent eU_3O_8, 0.001–0.006: 582.

Loomis No. 2 well, analysis by Rex and Morris Drilling Co.: range in percent eU_3O_8, 0.000–0.006: 582.

Loomis No. 7 well, analysis by Rex and Morris Drilling Co.: range in percent eU_3O_8, 0.000–0.007: 582.

Loomis No. 10 well, analysis by Cosmic Oil Co.: range in percent eU_3O_8, 0.000–0.002: 582.

Lychlyter (?) well, analysis by Palmer Co.: range in percent eU_3O_8, 0.000–0.006: 582.

Moyle No. 2 well, analysis by Hammer and Maclean Drilling Co.: range in percent eU_3O_8, 0.000–0.005: 582.

Moyle No. 4 well, analysis by Hammer and Maclean Drilling Co.: range in percent eU_3O_8, 0.000–0.006: 582.

Palmer No. 7A well, analysis by Magnolia Petroleum Co.: range in percent eU_3O_8, 0.001–0.006: 582.

Perry No. 1 well, analysis by Aikman and others: range in percent eU_3O_8, 0.001–0.003: 582.

Sanford No. 1 well, analysis by Alter and Brackensiek: range in percent eU_3O_8, 0.000–0.006: 582.

Scully No. 29 well, analysis by Sinclair Oil Co.: range in percent eU_3O_8, 0.000–0.004: 582.

Scully No. 120 well, analysis by Cities

Service Oil Co.: range in percent eU_3O_8, 0.000–0.004: 582.
South Anderson No. 1 well, analysis by Aikman and Braden: range in percent eU_3O_8, 0.000–0.010: 582.
South Anderson No. 2 well, analysis by Aikman and Braden: range in percent eU_3O_8, 0.000–0.002: 582.
South Anderson No. 7 well, analysis by Magnolia Petroleum Co.: range in percent eU_3O_8, 0.030: 582.
South Anderson No. 9 well, analysis by Magnolia Petroleum Co.: range in percent eU_3O_8, 0.000–0.002: 582.
Suits No. 1 well, analysis by Hammer and Maclean Drilling Co.: range in percent eU_3O_8, 0.000–0.002: 582.
Suits No. 9 well, analysis by Magnolia Petroleum Co.: range in percent eU_3O_8, 0.000–0.005: 582.
Taylor No. 1 well, analysis by Adkins Co.: range in percent eU_3O_8, 0.001–0.006: 582.
Thompson No. 1 well, analysis by Palmer Co.: range in percent eU_3O_8, 0.000–0.007: 582.
West No. 1 well, analysis by Richmond and Riegle: range in percent eU_3O_8, 0.000–0.007: 582.
Wilson No. 1½ well, analysis by Blakeslee and others: range in percent eU_3O_8, 0.000–0.002: 582.
Cowley County—
Dilworth Fee No. 1 well, analysis by Dilworth and Miller: range in percent eU_3O_8, 0.002–0.003: 582.
Dilworth Fee No. 2 well, analysis by Dilworth and Miller: range in percent eU_3O_8, 0.003: 582.
Elk County—
Shipley No. 1 well, analysis by Bird and Hanley: range in percent eU_3O_8, 0.000–0.007: 582.
Marion County—
Joliffe No. 1 well, analysis by Berry and Eells Co.: range in percent eU_3O_8 for two sets of samples: 0.001–0.004 and 0.000–0.003; for four other samples from drilling mud, the results were 0.003, 0.004, 0.005, and 0.007 mg. uranium/liter: 582.
Nonken No. 1 well, analysis by Progressive Co.: range in percent eU_3O_8, 0.000–0.008: 582.
Unnamed well, analysis by Fleet Co.: range in percent eU_3O_8, 0.002–0.004: 582.
Wenger No. 1 well: range in percent eU_3O_8, 0.001–0.004: 582.
Sedgwick County—
Keys No. 3 well, analysis by Vickers and Hinkle: range in percent eU_3O_8, 0.000–0.005: 582.
Rimel No. 1 well, analysis by James Co.: range in percent eU_3O_8, 0.000–0.008: 582.
Rimel No. 2 well, analysis by Derby: range in percent eU_3O_8, 0.000–0.007: 582.
Soukup No. 1 well, analysis by Shawver and others: range in percent eU_3O_8, 0.001–0.005: 582.
Trustee No. 8 well, analysis by Fischer and Lauck: range in percent eU_3O_8, 0.000–0.003: 582.

RADIUM OCCURRENCES

Arkansas
See Uranium Occurrences—Arkansas: 624.

RARE EARTHS

Texas
Llano County—
Badu Hill, 4.5 mi. SW of Baringer Hill and 1 mi. N of Beverley: rare earth minerals in pegmatite dike, discovered in 1936 and mined for feldspar: 566.

RARE EARTHS, THORIUM-BEARING

Oklahoma
Comanche County—
Wichita Mountains: samples with columbite which may be accompanied by samarskite or pitchblende: 623.
Texas
Llano County—
Baringer Hill: pegmatite with uranium and thorium in rare earth minerals discovered in 1887 and worked through 1907 for yttria: 594; rare earth minerals, many radioactive, carrying beryllium, cerium, erbium, thorium, uranium, yttrium, and other rare elements, and found in a pegmatite dike cutting Pre-Cambrian granite: 626; locality now covered by waters of Lake Buchanan, a reservoir: 626.

RARE EARTHS, URANIUM-BEARING

Oklahoma
Comanche County—
Wichita Mountains: 583; samples with columbite which may be accompanied by samarskite or pitchblende: 623.
Texas
Llano County—
Baringer Hill: pegmatite with uranium and thorium in rare earth minerals discovered in 1887 and worked through 1907 for yttria: 594; rare earth minerals, many radioactive, carrying beryllium, cerium, erbium, thorium, uranium, yttrium, and other rare elements and found in a pegmatite dike cutting Pre-Cambrian granite: 626; locality now covered by waters of Lake Buchanan, a reservoir: 626.

ROWLANDITE OCCURRENCES

Texas
Llano County—
Baringer Hill: in pegmatite with many other rare earth minerals: 594.

S

SHALES, URANIUM-BEARING

Missouri
Ste. Genevieve County—
Ste. Genevieve, 5½ mi. N of: carnotite: 600.

T

THORIUM MINERALOGY

General
General: 12, 25.
Bibliography: 9, 571.
Bibliography of U.S.G.S. reports: 572.

THORIUM MINERALS

General
General: 12, 25.
Bibliography: 9, 571.
Bibliography of U.S.G.S. reports: 572.
Mineralogy
General—
General: 12, 25.
Bibliography: 9, 571.
Bibliography of U.S.G.S. reports: 572.

THORIUM OCCURRENCES

General
General: 12.
Bibliography: 9, 571.
Bibliography of U.S.G.S. reports: 572.
Arkansas
General—
Mississippi River channel: 20 samples of sand showed small amounts of allanite and/or monazite, usually both, in the heavy mineral separates, these amounts consisting of "Rare" and "Present in amounts less than one per cent but fairly common" for both minerals and also up to 1% for allanite: 609.
Greene County—
Lower Mississippi Valley—
Williana gravel formation on Crowley's Ridge in Sec. 19, T. 15 N., R. 4 E., N of Jonesboro: nonopaque heavy minerals present include fluorite, monazite, corundum, and undetermined minerals in small amounts: 579.
Hot Spring County—
Magnet Cove—
J. W. Kimzey property on Tufa Hill: radioactive samples of tufas, altered syenite dike, and a yellow-green earthy material: 581; radioactive samples showed from 0.003–0.063% eU in U.S.G.S. laboratory studies; comparable results obtained in U.S.A.E.C. studies: 581; uranium content too low to be of commercial interest: 581; radioactivity due, in part, to thorium content: 581.
Magnet Cove Rutile Company deposit: radioactivity in drill cores and samples in titanium deposits, primarily in those of the microcline calcite vein type: 581; radioactive samples gave from 0.002–0.046% eU_3O_8 and 0.005–0.012% U_3O_8 (chemical) in U.S.A.E.C. laboratory studies: 581; radioactivity of samples with unidentified radioactive mineral probably due more to thorium than to uranium content: 581.
S. F. Moore property at Tufa Hill: radioactive sample of siliceous tufa float showed 0.027% eU in U.S.G.S. laboratory studies; comparable results obtained in U.S.A.E.C. studies: 581; radioactivity due, in part, to thorium content: 581.
Howard County—
Beulah Green property, 1 mi. W of Mineral Springs: monazite traces in black sands of ilmenite concentration: 591; monazite may be obtained as by-product if ilmenite deposits prove sufficiently rich to develop: 591.
Bibliographies
General: 9, 571.
United States: 9, 571.
Iowa
General—
Iowan till: traces of monazite: 593.
Kansan till: traces of monazite: 593.
Peorian loess: traces of monazite: 593.
Fayette County—
West Union Cut: monazite traces in Peorian loess and Iowan till: 593.
Johnson County—
North Liberty Cut: monazite traces in Peorian loess: 593.
Louisiana
General—
Lower Mississippi Valley—
Atchafalaya River, mile 78: nonopaque heavy minerals present include fluorite, monazite, corundum, and undetermined minerals in small amounts in alluvium, natural levee silt: 579.
Bayou St. Vincent: nonopaque heavy minerals present include fluorite, monazite, corundum, and undetermined minerals in small amounts in alluvium, substratum gravels, at 250 ft. depth: 579.
Mississippi River channel: 40 samples of sand showed small amounts of allanite and/or monazite, usually both, in the heavy mineral separates, these amounts consisting of "Rare," "Rare in one of the two grades analyzed and absent in the other," "Present in amounts less than one per cent but fairly common," and up to 1% for allanite and up to 2% for monazite: 609.
Sand deposits: rare occurrences of allanite and monazite: 619.
Ascension Parish—
Lower Mississippi Valley—
Donaldsonville: nonopaque heavy minerals present include fluorite, monazite, corundum, and undetermined minerals in small amounts in alluvium, backswamp clay, at 17 ft. depth: 579.
East Baton Rouge Parish—
Lower Mississippi Valley—
Baton Rouge: nonopaque heavy minerals present include fluorite, monazite, corundum, and undetermined minerals in small amounts in (pass. 200 sieve) suspended load, Mississippi River: 579.
Plaquemines Parish—
General and in St. Bernard Parish: allanite and monazite in heavy separates of Mississippi River subdelta sands: 577.
St. Bernard Parish—
General and in Plaquemines Parish: allanite and monazite in heavy separates of Mississippi River subdelta sands: 577.

*Minnesota**
Anoka County—
Coon Creek: soil, dune sand, 28 g. Ra × 10^{14}, 27 g. Th × 10^{7}, 96 Th/Ra × 10^{-6}: 611.
Beltrami County—
Bemidji: soil, outwashed plain from late Wisconsin drift, 25 g. Ra × 10^{14}, 34 g. Th × 10^{7}, 136 Th/Ra × 10^{-6}: 611.
Carlton County—
Cloquet: soil, moraine from early Wisconsin drift, 13 g. Ra × 10^{14}, 32 g. Th × 10^{7}, 246 Th/Ra × 10^{-6}: 611.
Clay County—
Manitoba Junction: soil, Red River Valley, boulder-clay, late Wisconsin drift, 62 g. Ra × 10^{14}, 60 g. Th × 10^{7} 97 Th/Ra × 10^{-6}: 611.
Cook County—
Pigeon Point diabase: allanite: 618.
Fillmore County—
Preston: soil, loess, 64 g. Ra × 10^{14}, 47 g. Th × 10^{7}, 73 Th/Ra × 10^{-6}: 611.
Hennepin County—
University Farm: soil, till coating on outwashed plain from late Wisconsin drift, 75 g. Ra × 10^{14}, 71 g. Th × 10^{7}, 95 Th/Ra × 10^{-6}: 611.
Hubbard County—
Guthrie: soil, outwashed plain from late Wisconsin drift, 27 g. Ra × 10^{14}, 25 g. Th × 10^{7}, 93 Th/Ra × 10^{-6}: 611.
Lake County—
Snowbank Lake: allanite in syenite: 610.
Norman County—
Twin Valley: soil, sandy plain, Lake Agassiz, rich in nitrogen, 17 g. Ra × 10^{14}, 28 g. Th × 10^{7}, 165 Th/Ra × 10^{-6}: 611.
Pine County—
Nickerson: soil, sandy deposit on moraine from early Wisconsin drift, 24 g. Ra × 10^{14}, 32 g. Th × 10^{7}, 133 Th/Ra × 10^{-6}: 611.
Willow River: soil, outwashed plain from early Wisconsin drift, 20 g. Ra × 10^{14}, 32 g. Th × 10^{7}, 160 Th/Ra × 10^{-6}: 611.
Pope County—
Cyrus: soil, Red River Valley, boulder-clay, and late Wisconsin drift, 80 g. Ra × 10^{14}, 64 g. Th × 10^{7}, 80 Th/Ra × 10^{-6}: 611.
Rock County—
Luverne: soil, loess, 64 g. Ra × 10^{14}, 41 g. Th × 10^{7}, 64 Th/Ra × 10^{-6}: 611.
St. Louis County—
Giants Range Batholith: allanite as an accessory mineral in granite: 559.
High Lake area in Vermilion Batholith: allanite as an accessory mineral in segregated magnetite bands: 585.
Vermilion Batholith: allanite in granite: 586.
St. Louis-Lake Counties—
Birch Lake: allanite in normal gabbro: 618.
Stearns County—
Quarry at St. Cloud: allanite as an accessory mineral in Rockville granite: 615.
Todd County—
Philbrook: soil, outwashed plain from late Wisconsin drift, 20 g. Ra × 10^{14}, 29 g. Th × 10^{7}, 145 Th/Ra × 10^{-6}: 611.

Mississippi River
General—
Channel between Cairo, Illinois, and Gulf of Mexico: 64 samples taken at intervals between the two points showed small amounts of allanite and/or monazite, usually both, in the heavy mineral separates, the amounts being classified as "Rare," "Rare in one of the two grades analyzed and absent in the other," "Present in amounts less than one per cent but fairly common," and up to 1% for allanite and up to 2% for monazite: 609.
Missouri
General—
Mississippi River channel: 4 samples of sands examined; in heavy mineral separates, two samples showed allanite and monazite "Present in amounts less than one per cent but fairly common," and 2 other samples showed only monazite, in one as "Rare" and in the other as "Present in amounts less than one per cent but fairly common": 609.
Nebraska
Seward County—
Milford: monazite, trace: 11.
Oklahoma
Comanche County—
Quanah granite in Quanah Mountain in Wichita Mts.: uranium and thorium in metamict and fresh zircon in pegmatite: 595.
Wichita Mountains: traces of uranium and thorium in pegmatite dike associated with zircon crystals: 574; rare earths with columbite which may be accompanied by samarskite or pitchblende: 623.
Rare Earths, Thorium-bearing
Oklahoma—
Comanche County—
Wichita Mountains: samples with columbite which may be accompanied by samarskite or pitchblende: 623.
Texas—
Llano County—
Baringer Hill: pegmatite with uranium and thorium in rare earth minerals discovered in 1887 and worked through 1907 for yttria: 594; rare earth minerals, many radioactive, carrying beryllium, cerium, erbium, thorium, uranium, yttrium, and other rare elements and found in a pegmatite dike cutting Pre-Cambrian granite: 626; locality now covered by waters of Lake Buchanan, a reservoir: 626.
South Dakota
General—
Black Hills: monazite with uranium minerals in pegmatites: 570; monazite in placers: 606; small traces of monazite in gold placers: 567; general geology of the area: 570.
Pre-Cambrian granite domes: allanite: 608.
Custer County—
Black Hills—
Custer: autunite, torbernite, uraninite, monazite in pegmatites: 606.

* See footnote, page 279.

THORIUM OCCURRENCES (contd.)
Harney Peak Region—
Harney Peak granite from area near Custer: monazite occurs with autunite, torbernite, uraninite in amblygonite-type and spodumene-type pegmatite phases of the granite and alone in placer deposits: 620.
Lawrence County—
Tinton: monazite, 6 lbs. per ton: 11.
Pennington County—
Black Hills—
Ingersoll claim: uraninite with some alteration to gummite and uranophane: 576; analyses gave UO_3, 28.582%, UO_2, 48.87%, and ThO_2, 2.15%: 576; geological age determinations by lead-uranium-thorium method gave 66.898% U, 15.243% Pb, and 1.889% Th or an age of 1667 million years: 576; mineralogy: 576.
Keystone District—
Etta mine on Etta Knob near Keystone: autunite, torbernite, uraninite, monazite in pegmatites: 606; autunite, monazite reported: 568; autunite and monazite associated with tin deposits in pegmatites: 602; monazite: 590; geology: 568; ownership and mining work: 568; commercial deposits of other minerals: 568.
Newtons Fork: monazite in placers: 621.
Spring Creek: monazite in placers: 621.
Texas
General—
General: 25.
Burnet County—
General: gadolinite: 78.
Fayette County—
Catahoula formation: monazite with heavy minerals in sand: 563.
Lower Oakeville formation: monazite with heavy minerals in sand: 563.
Upper Fayette formation: monazite with heavy minerals in sand: 563.
Gulf Coast—
Brazos River: monazite in beach sands: 565.
Colorado River: monazite in beach sands: 565.
Neches River: monazite in beach sands: 565.
San Antonio River, mouth: monazite in beach sands: 565.
Llano County—
General: allanite: 249; gadolinite: 397.
Baringer Hill: locality now covered by waters of Lake Buchanan, a reservoir: 626; allanite, cyrtolite, fergusonite, mackintoshite, nivenite, polycrase, thorogummite: 82, and gadolinite: 78; allanite, gadolinite, cyrtolite, fergusonite sometimes with a coating of autunite, uranite (nivenite) surrounded by gummite, mackintoshite, polycrase, rowlandite, yttrialite, and other oxidation products besides autunite and gummite in pegmatite: 594; pegmatite with rare earth minerals discovered in 1887 and worked through 1907 for yttria: 594; fergusonite, gummite, mackintoshite, nivenite, thorogummite, yttrialite: 589; mackintoshite with 45.30 ThO_2 and 22.4 UO_2 by chemical analysis; mineralogy: 580; rare earth minerals, many radioactive, carrying beryllium, cerium, erbium, thorium, uranium, yttrium, and other rare elements, and found in a pegmatite dike cutting Pre-Cambrian granite: 626; thorogummite with 41.44 ThO_2 and 22.43 UO_3 by chemical analysis; mineralogy: 580; mineralogy: 594; sequence of mineralization: 594.
Kingsland: allanite: 78, 82.
United States
General—
General: 12, 25.
Mississippi River channel from Cairo, Illinois, to Gulf of Mexico: 64 samples taken at intervals between the two points showed small amounts of allanite and/or monazite, usually both, in the heavy mineral separates, the amounts being classified as "Rare," "Rare in one of the two grades analyzed and absent in the other," "Present in amounts less than one per cent but fairly common," and up to 1% for allanite, and up to 2% for monazite: 609.
Bibliographies—
Bibliography: 9, 571.
Zircon, Thorium-bearing
Oklahoma—
Comanche County—
Quanah granite in Quanah Mountain in Wichita Mts.: uranium and thorium in metamict and fresh zircon in pegmatite: 595.

THOROGUMMITE MINERALOGY

General
Chemical Analyses: Baringer Hill, Texas, specimen: 580.
X-ray Pattern: Baringer Hill, Texas, specimen, like thorite when unheated: 580.

THOROGUMMITE OCCURRENCES

Texas
Llano County—
Baringer Hill: 78, 82, 589; thorogummite with 41.44 ThO_2 and 22.43 UO_3 by chemical analysis; mineralogy: 580.

TORBERNITE OCCURRENCES

South Dakota
General—
Black Hills: in pegmatites: 570.
Custer County—
Black Hills—
Custer: with autunite, monazite, uraninite in pegmatites: 606.
Harney Peak Region—
Harney Peak granite from area near Custer: occurs with autunite, monazite, uraninite in amblygonite-type and spodumene-type pegmatite phases of the granite and with autunite in quartz veins: 620.
Lawrence County—
Black Hills—
Ross Hannibal mine SE of Terry: 82.

Pennington County—
Black Hills—
General: mineralogical description: 621.
Keystone District—
Etta mine on Etta Knob near Keystone: with autunite, monazite, uraninite in pegmatites: 606.
Keystone: 78, 82; with autunite in pegmatites: 621.
Poisoned Ox claim, a copper prospect near Pactola: green uranium mica, probably torbernite: 621.

TYUYAMUNITE OCCURRENCES

Texas
Hudspeth County—
Trans-Pecos Region—
Rossman prospect, 3 mi. NNE of Allamoore Post Office: visible as secondary uranium mineralization: 588.

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URANINITE MINERALOGY

General
Age Determinations—
Geological age determinations by Lead-Uranium-Thorium method: South Dakota specimen: 576.
Detailed description of analytical methods used: South Dakota specimen: 576.
Chemical Analyses: South Dakota specimen: 576.

URANINITE OCCURRENCES

South Dakota
General—
Black Hills: in pegmatites: 570.
Custer County—
Black Hills—
Custer: with autunite, monazite, torbernite, in pegmatites: 606.
Custer Mountain (Skookum) feldspar mine: uraninite reported as rare in core in pegmatite: 604.
Harney Peak Region—
Harney Peak granite from area near Custer: occurs with autunite, monazite, torbernite in the amblygonite-type and spodumene-type pegmatite phases of the granite: 620.
Lawrence County—
Black Hills—
Bald Mountain: 7, 621.
Ross Hannibal mine in Ruby Basin: 104.
Pennington County—
Black Hills—
Bob Ingersoll mine near Keystone: 616.
Harney Peak: 616.
Ingersoll claim: uraninite with some alteration to gummite and uranophane: 576; analyses gave UO_2, 28.582%, UO_3, 48.87%, and ThO_2, 2.15%: 576; geological age determinations by lead-uranium-thorium method gave 66.898% U, 15.243% Pb, and 1.889% Th or an age of 1667 million years: 576; mineralogy: 576.
Keystone District—
Etta mine on Etta Knob near Keystone: with autunite, monazite, torbernite in pegmatites: 606; uraninite reported in intermediate zones in pegmatite: 604.
Ingersoll Dike No. 2 of Bob Ingersoll mine: uraninite reported as rare in intermediate zones in pegmatite: 604; in pegmatite: 70.
Peerless mine: uraninite reported in intermediate zones in pegmatite: 604.
Texas
Llano County—
Baringer Hill: 7.

URANITE OCCURRENCES

Texas
Llano County—
Baringer Hill: in pegmatite with many other rare earth minerals: 594.

URANIUM EXPLORATION

General
General: prospectors' guide: 90.
Bibliographies—
Bibliography: 571.
Bibliography of U.S.G.S. reports: 572.
Drilling Methods—
Diamond drilling: South Dakota: 629.
South Dakota: diamond drilling: 629.
Geobotanical Exploration
Bibliography: 571.
Bibliography of U.S.G.S. reports: 572.
Geochemical Exploration
Bibliography: 571.
Bibliography of U.S.G.S. reports: 572.
Geophysical Exploration
Bibliography: 571.
Bibliography of U.S.G.S. reports: 572.
Geophysical Exploration (Airborne)
Bibliography: 571.
Bibliography of U.S.G.S. reports: 572.
Geophysical Exploration (Ground)
Bibliographies—
Bibliography: 571.
Bibliography of U.S.G.S. reports: 572.
Kansas—
Cherokee County—
Tri-State District: Geiger-Mueller Counter Surveys: proved of no value in location of orebodies or delineating major structural features in this area: 578; radioactivity traverses showed no relation to underlying structure: 578; traverses made above both mined and unmined areas in the lead-zinc district: 578.
Kansas
Cherokee County—
Geophysical Exploration (Ground)—
Tri-State District: Geiger-Mueller Counter Surveys: proved of no value in location of orebodies or delineating major structural features in this area: 578; radioactivity traverses showed no relation to underlying structure: 578; traverses made above both mined and unmined areas in the lead-zinc district: 578.
Missouri
General: prospectors' guide: 599.

URANIUM EXPLORATION (contd.)
Prospectors' Guides
General: 90
Bibliography: 9, 571.
Missouri: 599.
South Dakota
Drilling Programs—
U.S.A.E.C. (work done by the Minerals Engineering Co.): 629.
Fall River County—
Edgemont: Minerals Engineering Co. under contract to diamond drill a maximum of 50,000 ft. for U.S.A.E.C. using four drills: 629.
Suggestions to Prospectors: all carnotite exposures should be examined with Geiger counters or scintillometers, especially exposures of thin-bedded sandstone within 30 ft. above and 70 ft. below the carbonaceous shale: 603; all benches between massive sandstone beds should be examined with Geiger counters or scintillometers and trenches dug in areas of high count: 603; all exposures containing carnotite parallel to bedding should be prospected by blasting: 603; all exposed high grade orebodies should be mined out to get the trend of the deposits: 603; carbonaceous shale may serve as an ore guide since favorable zones for carnotite appear to lie 20–30 ft. above the shale or at three levels below it at 25–30 ft., 45–50 ft., and 65–70 ft. respectively: 603; carnotite-bearing rock mined during prospecting should be sorted to obtain ore containing 0.1% or more uranium in order to determine the percentage of salable ore mineable from each deposit: 603; many carnotite-bearing samples are out of equilibrium indicating that higher grade ore may be found underground beyond areas of surface leaching: 603.
Texas
General—
Trans-Pecos Region: numerous localities examined by geologic and radiometric reconnaissance surveys, car-borne scintillometer traverses, etc: 588.
United States
General—
Bibliography: 9, 571.
Bibliography of U.S.G.S. reports: 572.
Prospectors' Guides: 90.
U.S.A.E.C. exploration program: U.S.G.S. participation: 405.

URANIUM MINERALOGY

General
General: 12, 25.
Bibliography: 9, 571.
Bibliography of U.S.G.S. reports: 572.

URANIUM MINERALS

General
General: 12, 25, 90.
Bibliography: 9, 571.
Bibliography of U.S.G.S. reports: 572.
Mineralogy
General—
General: 12, 25, 90.
Bibliography: 9, 571.
Bibliography of U.S.G.S. reports: 572.

URANIUM OCCURRENCES

General
General: 12, 13, 90.
Bibliographies—
Bibliography: 9, 10, 571.
Bibliography of U.S.G.S. reports: 572.
Geology: 90.
Mineralogy: 90.
Types of deposits: 90.
Agates, Uranium-bearing
Nebraska—
Dawes County—
Hay Springs, 50 mi. from: 573.
Arkansas
General—
Northwest part: uranium in Chattanooga shale; radioactivity equivalent to that of the type Chattanooga shale in Tennessee: 426.
Benton County—
Ozark Mountains: radium discovery: 624; samples laid on photographic plates showed radioactivity: 624; 800 acres along Missouri border purchased by John P. Nagle (or Nagel); entrance gained through large cave and thousands of tons of ore showing radioactivity already blocked out: 624.
Garland County—
Hot Springs: uranium in radioactive springs: 294.
Hot Springs Reservation on W slope of Hot Springs Mountain: radioactivity of spring waters tested: 562; water samples from 44 springs tested and showed gaseous, radioactive constituent properties identical with those of radium emanation: 562; observed activity per liter of water ranged from 0.4 to 91.6 $\times$ 10^{-4} g. uranium in samples from 44 hot springs; and 6.0 and 18.1 $\times$ 10^{-4} g. uranium in two samples from cold springs: 562; methods used: 562.
Potash-Sulphur Springs area, 10 mi. E of Hot Springs: uranium: 627.
Hot Spring County—
Magnet Cove—
J. W. Kimzey property on Tufa Hill: radioactive samples of tufas, altered syenite dike, and a yellow-green earthy material: 581; radioactive samples showed from 0.003–0.063% eU in U.S.G.S. laboratory studies; comparable results obtained in U.S.A.E.C. studies: 581; uranium content too low to be of commercial interest: 581; radioactivity due, in part, to thorium content: 581.
Magnet Cove Rutile Company deposit: radioactivity in drill cores and samples in titanium deposits, primarily in those of the microcline calcite vein type: 581; radioactive samples gave from 0.002–0.046% eU_3O_8 and 0.005–0.012% U_3O_8 (chemical) in U.S.A.E.C. laboratory studies: 581; radioactivity of samples with unidentified radioactive mineral probably due more to thorium than to uranium content: 581.

S. F. Moore property at Tufa Hill: radioactive sample of siliceous tufa float showed 0.027% eU in U.S.G.S. laboratory studies; comparable results obtained in U.S.A.E.C. studies: 581; radioactivity due, in part, to thorium content: 581.
Montgomery County—
General: uranium: 613.
Bibliographies
General: 9, 571.
Bibliography of U.S.G.S. reports: 572.
Kansas—
Bibliography of U.S.G.S. reports: 572.
North Dakota—
Bibliography of U.S.G.S. reports: 572.
South Dakota—
General: 601.
Bibliography of U.S.G.S. reports: 572.
Texas—
Bibliography of U.S.G.S. reports: 572.
United States—
General: 9, 10, 571.
Bibliography of U.S.G.S. reports: 572.
Black Shales, Uranium-bearing
Arkansas—
General—
Northwest part: uranium in Chattanooga shale; radioactivity equivalent to that of the type Chattanooga shale in Tennessee: 426.
Kansas—
General—
Bourbon formation, Top of: uranium in phosphatic nodules in shales: 462.
Bourbon formation and Hushpuckney and Stark shales: uranium in phosphatic nodules in black shales: 405.
Hushpuckney and Stark shales: uranium: 462.
Pennsylvanian black shales in eastern part: uranium contained in phosphate nodules in shale amounting to 136 g. uranium per ton of shale: 607; uranium content can be extracted during phosphate production: 607.
Pennsylvanian shales: uranium and thorium present in black shales with highest content in the phosphatic nodules: 426.
Bourbon County—
Mulky coal in Cherokee fm. at an outcrop: coal bed overlain by black shale with phosphatic nodules containing 0.011% uranium oxide: 582.
Missouri—
Ste. Genevieve County—
Charles Bussen quarry N of Ste. Genevieve: uranium in finely disseminated carbonaceous material and purple fluorite contained in the Mississippian Spergen limestone, which also encloses thin black shale beds molded into stylolitic structures and containing 0.6% uranium, more than 100 times greater than in the average shales of the Chattanooga and Pennsylvanian type; carnotite in limestone adjacent to black shale may have been leached from shale and transported by groundwater: 426.
Ste. Genevieve, 5½ mi. NE of: carnotite: 600.
Oklahoma—
General—
Checkerboard and Fort Scott limestones: uranium in phosphatic nodules in black shales: 405.
Northeast part; uranium in Chattanooga shale; radioactivity equivalent to that of the type Chattanooga shale in Tennessee: 426.
Pennsylvanian black shales at top of Checkerboard limestone member of Coffeyville fm. and of Fort Scott (or Oswego) limestone: uranium in phosphatic nodules: 462.
Pennsylvanian shales: uranium and thorium present in black shales with highest content in phosphatic nodules: 426.
South central part: uranium in Woodford chert; radioactivity equivalent to that of the type Chattanooga shale in Tennessee: 426.
Woodford chert: uranium: 405, 462.
United States—
General: 27.
Clays, Uranium-bearing
Missouri—
Franklin County—
Eliza Gelauf property about 5½ mi. SE of Gerald: meta-torbernite, chiefly on spheroidal masses of "bad" clay or so-called "sore spots" in flint fire clay: 584, 599.
Fluorite, Uranium-bearing
Missouri—
Ste. Genevieve County—
Charles Bussen quarry N of Ste. Genevieve: uranium in finely disseminated carbonaceous material and purple fluorite contained in the Mississippian Spergen limestone, which also encloses thin black shale beds molded into stylolitic structures and containing 0.6% uranium, more than 100 times greater than in the average shale of the Chattanooga and Pennsylvanian type; carnotite in limestone adjacent to the black shale may have been leached from shale and transported by groundwater: 426.
Kansas
General—
Bandera shale: possible uranium source which should be investigated further: 462.
Bibliography of U.S.G.S. reports: 572.
Bourbon formation, Top of: uranium in phosphatic nodules in shales: 462.
Bourbon formation and Hushpuckney and Stark shales: uranium-bearing phosphatic nodules in black shales: 405.
Hushpuckney and Stark shales: uranium: 462.
Oil wells: gamma ray logs show black shales equivalent in radioactivity to type Chattanooga shale in Tennessee and its Woodford chert equivalent: 426.
Pennsylvanian black shales in eastern part: uranium contained in phosphate nodules in shale amounting to 136 g. uranium per

URANIUM OCCURRENCES (contd.)
ton of shale: 607; uranium content can be extracted during phosphate production: 607.
Pennsylvanian Cherokee shale: possible uranium source which should be investigated further: 462.
Pennsylvanian shales: uranium and thorium in black shales with highest content in the phosphatic nodules: 426.
Southeast part: uraniferous deposits in Paleozoic bituminous coal stratigraphically controlled: 443.
Bourbon County—
Mulky coal in Cherokee fm. at an outcrop: coal bed overlain by black shale with phosphatic nodules containing 0.011% uranium oxide: 582.
Butler County—
North Augusta oil field in southeast part: radium- and hydrocarbon-bearing Ordovician and Pennsylvanian dolomites and limestones: 426.
Southeast Part—
Oil and Gas fields: uranium believed to be present in greater-than-normal amounts in subsurface rocks because of abnormally high concentrations of radium in precipitates and drill samples, concentration of radium in comparatively small areas, and presence of helium, probably of radiogenic origin, in oil and gas fields where radium-bearing precipitates formed: 582; presence, in altered limestones, of minerals, probably formed as a result of introduction of hydrothermal solutions, suggests localization of uranium in hydrothermal deposits, possibly of the vein type: 582; radium-bearing precipitates may have been derived from solution and redeposition from the radium-bearing rocks in the Kansas City and Arbuckle groups but absence of uranium and radium in equilibrium quantities in these rocks may indicate that uranium was removed from them within the past thousand years; vuggy nature of rock fragments in drill samples suggests that uranium was leached from the rocks only recently, possibly by the drilling fluids when wells were drilled: 582.
Lignites, Uranium-bearing
North Dakota—
General—
General: 27, 62.
Southwest part: uranium in Paleocene and Eocene lignites; greatest concentrations in first group of beds below Paleocene-Eocene unconformity; uranium content slightly more than 0.01%: 426.
South Dakota—
General—
General: 27, 62; origin of uranium deposits, probably due to downward migration from radioactive tuffs in overlying Oligocene White River formation and Arikaree formation of Miocene age: 261.
Northwest part: uranium in Paleocene and Eocene lignites; greatest concentrations in first group of beds below Paleocene-Eocene unconformity; uranium content slightly more than 0.01%: 426.
United States—
General: 27.
Limestones, Radium-bearing
Kansas—
Butler County—
North Augusta oil field in southeast part: radium- and hydrocarbon-bearing Ordovician and Pennsylvanian dolomites and limestones: 426.
Limestones, Uranium-bearing
Missouri—
General: 27.
Ste. Genevieve County—
Charles Bussen quarry N of Ste. Genevieve: uranium in finely disseminated carbonaceous material and purple fluorite contained in the Mississippian Spergen limestone, which also encloses thin black shale beds molded into stylolitic structures and containing 0.6% uranium, more than 100 times greater than in the average shales of the Chattanooga and Pennsylvanian type; carnotite in limestone adjacent to black shale may have been leached from shale and transported by groundwater: 426.
Ste. Genevieve, 5½ mi. N of: carnotite: 600.
United States—
General: 27.
Missouri
General—
General: uranium-bearing limestone: 27.
Flint clays: radioactivity present in those with and without black clay and carbonaceous material: 599.
Pennsylvanian Cherokee shale: possible uranium source which should be investigated further: 462.
Southeast part: uranium in Mississippian Spergen limestone; deposits stratigraphically controlled: 443.
Franklin County—
Eliza Gelauf property about 5½ mi. SE of Gerald: meta-torbernite in tiny scales chiefly on spheroidal masses of "bad" clay or so-called "sore spots" in flint fire clay and associated with barite and small amounts of chalcopyrite and limonite: 584, 599; first radioactive occurrence reported in the state: 584, 599; mineralogical characteristics: 584, 599.
Gasconade County—
Owensville: meta-torbernite in flint clay from sinkhole type pit: 564; first radioactive occurrence reported in the state: 564.
Ste. Genevieve County—
Charles Bussen quarry N of Ste. Genevieve: carnotite as thin film along joint surface in limestone of Spergen (Mississippian) formation: 599; highly radioactive black carbonaceous shale parting between two limestone beds near top of quarry face showed radioactivity of 0.37% eU; shale phosphatic but uranium mineral not

identified; also contained vanadium in the clay mineral, illite: 599; uranium in finely disseminated carbonaceous material and purple fluorite contained in the Mississippian Spergen limestone, which also encloses thin black shale beds molded into stylolitic structures and containing 0.6% uranium, more than 100 times greater than in the average shales of the Chattanooga and Pennsylvanian type; carnotite in limestone adjacent to black shale may have been leached from shale and transported by groundwater: 426.
Ste. Genevieve, 5½ mi. N of: carnotite in limestone and shale: 600.
Saline County—
Sweet Springs: uranium in radioactive springs: 294.
Nebraska
Dawes County—
Hay Springs, 50 mi. from: uranium-bearing fluorescent agate: 573.
North Dakota
General—
General: uranium mineral, probably becquerelite, in lignites: 493.
Bibliography of U.S.G.S. reports: 572.
Lignites, Uranium-bearing: 27, 62.
Southwest part: uranium in Paleocene and Eocene lignites with greatest concentrations in first group of beds below the Paleocene-Eocene unconformity: 426; uranium content of lignite beds varies but some contain slightly more than 0.01%: 426; uranium-bearing lignites; stratigraphically controlled: 443; origin of uranium in Paleocene and Eocene lignites may be by leaching from volcanic ash in White River formation and introduction into the lignites by surface waters in post-Paleocene time but the even distribution of uranium in lignite, as shown by autoradiograph of one North Dakota specimen, and the absence of apparent concentration of uranium on fracture planes in area suggest uranium was present before coalification: 426.
Oklahoma
General—
Bandera shale: possible uranium source which should be investigated further: 462.
Caney shale: possible uranium source which should be investigated further: 462.
Checkerboard and Fort Scott limestones: uranium-bearing phosphatic nodules in black shales: 405.
North central part: uraniferous deposits in sandstone stratigraphically controlled: 443.
Northeast part: uranium in Chattanooga shales; radioactivity equivalent to that of the type Chattanooga shale in Tennessee: 426.
Oil wells: gamma ray logs show black shales equivalent in radioactivity to type Chattanooga shale in Tennessee and its Woodford chert equivalent: 426.
Pennsylvanian black shales at top of Checkerboard limestone member of Coffeyville formation and of Fort Scott (or Oswego) limestone: uranium in phosphate nodules: 462.
Pennsylvanian shales: uranium and thorium in black shales with highest content in the phosphatic nodules: 426.
South central part: uranium in Woodford chert; radioactivity equivalent to that of the type Chattanooga shale in Tennessee: 426.
Woodford chert: uranium: 462; uranium-bearing black shales: 405.
Comanche County—
Quanah granite in Quanah Mountain in Wichita Mts.: uranium and thorium in metamict and fresh zircon in pegmatite: 595.
Wichita Mountains: traces of uranium and thorium in pegmatite dike associated with zircon crystals: 574; uranium in rare earths: 583; rare earths with columbite which may be accompanied by samarskite or pitchblende: 623.
Pawnee County—
Staneart property: uraniferous asphalt deposits in Permian sandstone: 509.
Origin
Kansas—
Oil and Gas fields in southeast part: radium-bearing precipitates may have been derived from solution and redeposition from the radium-bearing rock in the Kansas City and Arbuckle groups, but absence of uranium and radium in equilibrium quantities in these rocks may indicate that uranium was removed from them or radium was introduced into them within the past thousand years; vuggy nature of rock fragments in drill samples suggests that uranium was leached from the rocks only recently, possibly by the drilling fluids when wells were drilled: 582; presence, in altered limestones, of minerals, probably formed as a result of introduction of hydrothermal solutions, suggests localization of uranium in hydrothermal deposits, possibly of the vein type: 582; uranium believed to be present in greater-than-normal amounts in subsurface rocks because of abnormally high concentrations of radium in precipitates and drill samples, concentration of radium in comparatively small areas, and presence of helium, probably of radiogenic origin, in oil and gas fields where radium-bearing precipitates were formed: 582.
Missouri—
Carnotite Occurrences—
Origin of carnotite in limestone adjacent to the black shale in Charles Bussen quarry: may have been leached from shale and transported by groundwater: 426.
North Dakota—
Lignites, Uranium-bearing—
Origin of uranium in Paleocene and Eocene lignites: may be by leaching from volcanic ash in White River formation and introduction into the lignite by surface waters in post-Paleocene time, but the even distribution of uranium in

URANIUM OCCURRENCES (contd.)
lignite, as shown by autoradiograph of one North Dakota specimen, and the absence of apparent concentration of uranium on fracture planes in area suggest uranium was present before coalification: 426.
South Dakota—
Autunite Occurrences—
Annie Creek area near Trojan: origin of autunite: uranium introduced into siltstone by hydrothermal solutions moving along contact of siltstone and underlying porphyry with the fractured siltstone forming the permeable zone for migration of solutions, which were probably related to late stage of hydrothermal activity accompanying intrusion of the porphyries: 617.
Lignites, Uranium-bearing—
Origin of uranium in lignites: probably due to downward migration from radioactive tuffs in overlying Oligocene White River formation and Arikaree formation of Miocene age: 261.
Origin of uranium in Paleocene and Eocene lignites: may be by leaching from volcanic ash in White River formation and introduction into the lignite by surface waters in post-Paleocene time, but the even distribution of uranium in lignite, and the absence of apparent concentration of uranium on fracture planes in area suggest uranium was present before coalification: 426.
Phosphorites, Uranium-bearing
Kansas—
General—
Bourbon formation, Top of: uranium in phosphatic nodules in shales: 462.
Hushpuckney and Stark shales: uranium: 462.
Oklahoma—
General—
Pennsylvanian black shales at top of Checkerboard limestone member of Coffeyville fm. and of Fort Scott (or Oswego) limestone: uranium in phosphate nodules: 462.
Woodford chert: uranium: 462.
Radioactive Springs
Arkansas—
Garland County—
Hot Springs: uranium: 294.
Missouri—
Saline County—
Sweet Springs: uranium: 294.
Radioactive Tufa
Arkansas—
Hot Spring County—
Magnet Cove—
J. W. Kimzey property on Tufa Hill: samples showed 0.003–0.063% eU but radioactivity due, in part, to thorium content: 581.
S. F. Moore property at Tufa Hill: sample of siliceous tufa float showed 0.027% eU but radioactivity due, in part, to thorium content: 581.
Rare Earths, Uranium-bearing
Oklahoma—
Comanche County—
Wichita Mountains: uranium: 583; samples with columbite which may be accompanied by samarskite or pitchblende: 623.
Texas—
Llano County—
Baringer Hill: pegmatite with uranium and thorium in rare earth minerals discovered in 1887 and worked through 1907 for yttria: 594; rare earth minerals, many radioactive, carrying beryllium, cerium, erbium, thorium, uranium, yttrium, and other rare elements and found in a pegmatite dike cutting Pre-Cambrian granite: 626; locality now covered by waters of Lake Buchanan, a reservoir: 626.
South Dakota
General—
General: 25; uranium mineral, probably becquerelite, in lignites: 493.
Black Hills: autunite, monazite, torbernite, uraninite in pegmatites: 570; general geology of area: 570; uranium-bearing Oligocene White River formation caps many hills and is overlain by slightly radioactive Miocene sandstone: 261; uranium deposits in Custer, Lawrence, and Pennington Cos. (See county listings for specific locations): 621.
Lignites, Uranium-bearing: 27, 62.
Northwest part: uranium in Paleocene and Eocene lignites with greatest concentrations in first group of beds below the Paleocene-Eocene unconformity: 426; uranium content of lignite beds varies but some contain slightly more than 0.01%: 426; uranium-bearing lignites; deposits stratigraphically controlled: 443; origin of uranium in Paleocene and Eocene lignites may be by leaching from volcanic ash in White River formation and introduction into the lignite by surface waters in post-Paleocene time, but the even distribution of uranium in lignite, as shown by autoradiograph of one North Dakota specimen, and the absence of apparent concentration of uranium on fracture planes in area suggest uranium was present before coalification: 426.
Origin of uranium in lignites, probably due to downward migration from radioactive tuffs in overlying Oligocene White River formation and Arikaree formation of Miocene age: 261.
Uranocircite: 592.
Bibliographies—
Bibliography: annotated and probably including a few older papers on uranium occurrences: 601.
Bibliography of U.S.G.S. reports: 572.
Black Hills—
General: uranium deposits in Custer, Lawrence, and Pennington Cos. (See county listings for specific locations): 621.
Bibliography: annotated; with some references to uranium occurrences: 601.

Custer County—
Black Hills—
Custer: autunite: 82; autunite, torbernite, uraninite, monazite in pegmatites: 606.
Custer District—
Tin Mountain mine: microlite reported in very small quantities in pegmatite: 604.
Custer Mountain (Skookum) feldspar mine: uraninite reported as rare in core in pegmatite: 604.
Harney Peak Region—
Harney Peak granite from area near Custer: uranium minerals occur with mica in the pegmatitic phases of this granite: amblygonite-type and spodumene-type pegmatite phases show autunite, monazite, torbernite, uraninite: 620; quartz veins show autunite, torbernite: 620; placer deposits show monazite: 620; paragenesis of all minerals in area: 620.
Spokane: autunite: 82.
Fall River County—
Coal Canyon, 4 mi. NW of Craven Canyon: carnotite in Lakota formation; material of probable ore grade averaging about one ft. thick crops out on two sides of a pointed spur or bench, indicating a fair tonnage of ore there although much prospecting remains to be done; ratio of U_3O_8 to V_2O_5 in carnotite may be about 1 to 2: 560.
Craven Canyon, 8 mi. N of Edgemont: carnotite as yellow fillings between sand grains, joint fillings, and as thin coatings at three horizons within the lower 150 ft. of the Lakota formation in deposits roughly parallel to the bedding or parallel to the long axes of broad lenses of thin-bedded sandstone, and similar to the uranium occurrences of the Colorado Plateau; ratio of U_3O_8 to V_2O_5 in carnotite is about 2 to 1: 560; carnotite deposits in Lakota sandstone first discovered in 1951; 603; accessibility of carnotite prospects: 603; descriptions of individual carnotite prospects: 603; general geology: carnotite prospects in Lakota sandstone overlain by Fuson shale on higher ridges and underlain by Morrison formation exposed in valleys; beds consist of uniformly fine-grained quartz and appreciable amounts of interstitial white clay; carnotite and limonite stains abundant on sandstone throughout the area and manganese oxides coat fractures and occur as spots in carnotite-bearing sandstone; unidentified dark to olive green stain coats sandstone near carnotite and chemical tests show presence of uranium and vanadium: 603; localization of carnotite deposits in lower 100 to 150 ft. of Lakota sandstone in three favorable zones: 603; location of carnotite prospects: 603; mineralogy: 603; ore deposits: 603; size and shape of carnotite deposits: 603; suggestions for prospecting on carnotite claims: 603.
Alice claim, adjoins Clara and Joan claims and is across canyon to W of Eunice claim: discovery pit exposes 3 to 5 ft. vertical thickness of carnotite ore that can be traced for about 40 ft. from the strike and may extend further; no samples taken but ore may be equivalent in grade to that in Dagmar claim, of which the occurrence is almost a duplicate: 603.
Dagmar claim, adjoins NE side of Betty claim and is across canyon N of Eunice claim: discovery pit, 5 ft. deep, at S corner of claim; carnotite at discovery pit and in float blocks with half-inch thick stringers of carnotite ore parallel to bedding and on steeply dipping joints and fractures, and disseminated throughout ore zone; channel sample of carnotite-bearing gray sandstone contained 0.062% eU and 0.039% U: 603.
Eggshell claim, adjoins Ophelia claim on north: carnotite occurs near fracture zone where two claims adjoin or overlap in two lenses about 20 to 25 ft. below carbonaceous shale; ore in one lense estimated to be of higher grade than that of sample from Ophelia claim which contained 0.14% eU, 0.20% U, and 0.10% V: 603.
Eunice claim, between Imogene and Lucy claims: discovery pit located about 400 ft. NW of Imogene discovery pit and at base of 50 ft. cliff of massive sandstone about 35 ft. above base of Lakota sandstone; carnotite present at discovery pit, also in high grade streaks as much as 0.05 ft. thick parallel to bedding and as disseminated blebs and stains scattered throughout massive sandstone; one vertical channel sample contained 0.024% eU and 0.015% U: 603.
Flora claim, adjoins Gertrude claim: carnotite stains visible about 20 ft. above papery-weathering, carbonaceous shale horizon and about 10 ft. below another thin carbonaceous shale and may be continuation of carnotite zone on Gertrude claim; second zone about 15–20 ft. above non-papery carbonaceous shale; carnotite-bearing talus blocks common below the cliff; no careful inspection or sampling carried out: 603.
Gertrude claim, N of Helen claim: contains one of highest grade orebodies in area with ore in relatively thin-bedded sandstone about 30 ft. above carbonaceous shale; carnotite evenly disseminated in 1 to 2 ft. massive sandstone bed overlying a more thinly bedded sandstone that is highly radioactive but only lightly stained with carnotite; high grade orebody is exposed for 35 ft. N and S with maximum width of 16 ft. (average, 12 ft.) and maximum observed thickness of 2 ft.; six samples from various parts of the orebody showed: 0.13% eU and 0.16% U; 0.16% eU, 0.16% U, and 0.08% V; 0.19% eU and 0.23% U; 0.19% eU, 0.19% U, and 0.04% V; 0.027% eU and 0.034% U; 0.004% eU and 0.002% U: 603.

URANIUM OCCURRENCES (contd.)
Helen claim, adjoins and overlaps Imogene claim on north: discovery pit exposes 8 ft. of sandstone, of which upper 4.7 ft. is white with 6-inch carnotite layer at top, but entire section is radioactive; sample from SE edge of discovery pit contained 0.044% eU, 0.049% U, and 0.04% V; carnotite stains also appear on overhanging cliff 20 to 30 ft. below pit: 603.
Imogene claim, on E side of canyon: only known carnotite deposit on claim is at discovery pit where a zone 5.5 ft. thick is exposed on corner of a cliff of relatively thin-bedded sandstone that crops out for about 15 ft. W and 15 ft. N of corner; high grade carnotite ore occurs on S and W side of corner in a lense about 5 ft. long and 2 ft. thick; sample from decomposed talus block at foot of cliff contained 0.23% eU and 0.33% U with this higher content of U over eU suggesting that much of the carnotite on claim was precipitated recently, and being substantiated by distribution of carnotite in thin bands parallel to bedding, fractures, and plant fossils; chip sample, more representative of ore available in entire deposit, contained 0.058% eU and 0.054% U: 603.
Lucy claim, N of Pictograph claim: discovery cut is a narrow adit about 6 ft. long at base of high vertical cliff of Lakota sandstone; visible carnotite is surface coating on coarse-grained porous sandstone and partly localized near plant fossils; a 5 ft. sample cut across two sandstone layers contained 0.030% eU, 0.032% U, and 0.02% V: 603.
Ophelia claim, adjoins Pictograph claim: Lakota sandstone exposed in cliff near SE corner of Pictograph claim and composed of massive sandstone beds as much as 20 ft. thick in its lower 60 to 80 ft. and discovery claim is about 20 ft. below carbonaceous shale and N and a little E of cliff; carnotite occurs as stains on quartz grains in streaks as much as 2 in. thick parallel to bedding; one vertical channel sample, considered representative of all material exposed in cut, contained 0.077% eU, 0.095% U, and 0.06% V; richest exposure on claim is 70 to 100 ft. NE of discovery pit and grab sample from it contained 0.14% eU, 0.20% U, and 0.10% V: 603.
Pictograph claim, located in 1951 and extending along W edge of NW¼ of Sec. 30 in unsectioned T. 7 S., R. 3 E.: only workings were at face of discovery pit at N end of triangular shaped mesa, where 16 individual exposures have been mapped on low cliffs at edges and other unmapped carnotite exposures occur on E edge; carnotite occurs in lenses parallel to bedding in thin-bedded sandstone; seven vertical channel samples showed a range from 0.045 to 0.26% eU and 0.040 to 0.30% U, and two grab samples contained 0.070 and 1.1% eU and 0.078 and 2.0% U respectively; several favorable zones found on this claim: 603; most notable deposit showing relatively high grade material with lense extending along cliff face for about 50 ft. and reaching a maximum thickness of over 3 ft.: 560.
Edgemont area: carnotite in Lakota sandstone: 53.
Red Canyon, 1½ mi. E of Craven Canyon: carnotite in Lakota formation in deposits reported to be more persistent and more heavily mineralized than the known deposits in Craven Canyon; small tonnage of high grade ore to be shipped from surface workings: 560.
Lawrence County—
Black Hills—
Black Hills, northern part: uranocircite as an accessory mineral in siliceous gold ores; location not named: 621.
Annie Creek W of Portland: autunite in porphyries (phonolite): 621.
Bald Mountain Mining District—
Annie Creek near Carbonate: uranium: 617.
Annie Creek near Trojan: autunite as fracture coatings and disseminations in siltstone of the Deadwood formation of Cambrian age and concentrated in lower two ft. of siltstone at contact with intrusive rhyolite porphyry, with purple fluorite and limonite as gangue minerals: 617; property located in 1890 for gold and silver on patented ground believed owned by Annie Creek Mining Co., but relocated for uranium in 1952: 617; geology: 617; mine workings include a partly caved adit, a 10-ft. winze, dump, several prospect pits: 617; mineralogy: 617; radiometric analyses of 5 autunite samples gave .008, .012, .030, .037, and .059% eU while chemical analyses for the same samples gave .004, .004, .020, .016, and .048% U: 617; origin of autunite: uranium introduced into siltstone by hydrothermal solutions moving along contact of siltstone and underlying porphyry with the fractured siltstone forming the permeable zone for migration of solutions, which were probably related to late stage of hydrothermal activity accompanying intrusion of the porphyries: 617.
Bald Mountain: pitchblende and uranium mica (probably autunite): 614; uraninite: 7, 621; mineralogy of deposit: 7.
Davier mine on Anna Creek near Portland: uranium: 617; uranium intimately associated with porphyry: 602.
Ross Hannibal mine in Ruby Basin: uraninite: 104.
Ross Hannibal mine SE of Terry: autunite in blue siliceous gold ore of Lower Cambrian age: 621; torbernite: 82.

Ross Hannibal mine, Whitetail Gulch: uranium mica: 592.
Pennington County—
Black Hills—
Black Hills near Keystone: autunite: 78.
Black Hills, northern part: uranocircite as an accessory mineral in siliceous gold ores; location not named: 621.
Bob Ingersoll mine near Keystone: autunite as a bright yellow coating on muscovite flakes and crystals and as seamlets in their cleavage planes in pegmatite dikes: 621; uraninite: 616.
Everly claim near Keystone: autunite as a bright yellow coating on muscovite flakes and crystals and as seamlets in their cleavage planes in pegmatite dikes: 621.
Harney Peak: autunite in pegmatites: 621; pitchblende in granite: 569; uraninite in granite: 616.
Ingersoll claim: uraninite with some alteration to gummite and uranophane: 576; analyses gave UO_3, 28.582%, UO_2, 48.87%, and ThO_2, 2.15%: 576; geological age determinations by lead-uranium-thorium method gave 66.898% U, 15.243% Pb, and 1.889% Th or an age of 1667 million years: 576; mineralogy: 576.
Keystone District—
Etta mine on Etta Knob near Keystone: autunite, monazite reported: 568; autunite and monazite associated with tin deposits in pegmatites: 602; autunite, torbernite, uraninite, monazite in pegmatites: 606; autunite as a bright yellow coating on muscovite flakes and crystals and as seamlets in their cleavage planes in pegmatite dikes: 621; uraninite reported in intermediate zones in pegmatite: 604; valuable uranium minerals in pegmatites: 596; commercial deposits of other minerals: 568; geology: 568; ownership and mining work: 568, 596.
Ingersoll Dike No. 1 of Bob Ingersoll mine: microlite, less than 5%, reported in core in pegmatite: 604.
Ingersoll Dike No. 2 of Bob Ingersoll mine: uraninite reported as rare in intermediate zone in pegmatite: 604; uraninite in pegmatite: 70.
Keystone: autunite, torbernite in pegmatites: 621; autunite, torbernite, uranocircite: 82; torbernite, uranocircite: 78.
Peerless mine: uraninite reported in intermediate zones in pegmatite: 604.
Peerless claim near Keystone: autunite as a bright yellow coating on muscovite flakes and crystals and as seamlets in their cleavage planes in pegmatite dikes: 621.
Poisoned Ox claim, a copper prospect near Pactola: green uranium mica, possibly, torbernite: 621.
Poisoned Ox mine near Pactola: uranium with copper in slates: 602; zeunerite first reported here in 1897: 617.
Rochford: pitchblende found on Charles Swanson land: 622; samples analyzed by eastern chemists: 622.
Texas
General—
General: 13, 25.
Bibliography of U.S.G.S. reports: 572.
Southwest part: uraniferous deposits in sandstone stratigraphically controlled: 443.
Trans-Pecos Region: scattered localities show small amounts of supergene uranium minerals and possibly pitchblende in one place but, in general, the area does not appear to be one where large concentrations of uranium minerals are expectable: 588; exploration through radiometric and geologic reconnaissance surveys, carborne scintillometer traverses, etc.: 588; geology: 588.
El Paso County—
Trans-Pecos Region—
East flank of Franklin Mts.: small amounts of radioactive material in pegmatitic granite: 588; no uranium or thorium minerals could be identified: 588; analyses of two select samples gave the following results: 0.025% eU_3O_8 and 0.004% U_3O_8 (chem.), and 0.019% eU_3O_8 and 0.009% U_3O_8 (chem.), the higher radiometric assay indicating recent leaching: 588.
Hudspeth County—
Trans-Pecos Region—
Rossman prospect, 3 mi. NNE of Allamoore Post Office: uranium mineralization in one small area of veinlets in an irregular fracture zone cutting a massive silicified limestone of the Pre-Cambrian Millican formation and with no disseminated minerals; visible secondary uranium mineralization in form of tyuyamunite and uranyl vanadate: 588; one selected chip sample taken across the veinlets gave 0.025% eU_3O_8 and 0.017% U_3O_8 (chem.), the higher radiometric assay indicating recent leaching of uranium by meteoric waters: 588; surrounding area showed no abnormal radioactivity and several other prospect pits had been filled by wash and could not be examined thoroughly: 588.
Llano County—
Baringer Hill: locality now covered by waters of Lake Buchanan, a reservoir: 626; allanite, cyrtolite, fergusonite, mackintoshite, nivenite, polycrase, thorogummite: 82; allanite, cyrtolite, fergusonite, gadolinite, mackintoshite, nivenite, polycrase, thorogummite: 78; allanite, gadolinite, cyrtolite, fergusonite sometimes with a coating of autunite, uranite (nivenite) surrounded by gummite, mackintoshite, polycrase, rowlandite, yttrialite, and other oxidation products besides autunite and gummite, in pegmatite: 594; pegmatite with rare earth minerals discovered in 1887 and worked through 1907 for yttria: 594; autunite, fergusonite, gummite, mackintoshite, nivenite, polycrase, thorogummite: 589; mackintoshite with 45.30

URANIUM OCCURRENCES (contd.)
ThO_2 and 22.4 UO_2 by chemical analysis; mineralogy: 580; rare earth minerals, many radioactive, carrying beryllium, cerium, erbium, thorium, uranium, yttrium, and other rare elements, and found in a pegmatite dike cutting Pre-Cambrian granite: 626; thorogummite with 41.44 ThO_2 and 22.43 UO_3 by chemical analysis; mineralogy: 580; uraninite: 7; mineralogy: 7, 594; sequence of mineralization: 594.
West Part—
Oil wells: gamma ray logs show black shales equivalent in radioactivity to type Chattanooga shale in Tennessee and its Woodford chert equivalent: 426.
Types
Hydrothermal Vein Deposits—
United States: general: 62.
Lignites, Uranium-bearing—
North Dakota: general: 62.
South Dakota: general: 62.
United States: general: 62.
United States
General—
General: 12, 13, 25, 90.
Bibliography: 9, 10, 571.
Bibliography of U.S.G.S. reports: 572.
Black Shales, Uranium-bearing: 27.
Lignites, Uranium-bearing: 27, 62.
Limestones, Uranium-bearing: 27.
Tertiary lignites in Great Plains: 63.
Zircon, Uranium-bearing
Oklahoma—
Comanche County—
Quanah granite in Quanah Mountain in Wichita Mts.: uranium and thorium in metamict and fresh zircon in pegmatite: 595.

URANIUM ORE GUIDES

South Dakota
Fall River County—
Geologic Guides—
Carbonaceous shale may serve as an ore guide since favorable zones for carnotite appear to lie 20–30 ft. above the shale or at three levels below it at 25–30 ft., 45–50 ft., and 65–70 ft. respectively: Craven Canyon: 603.

URANIUM PROCESSES

General
Bibliography of U.S.G.S. reports: 572.
Tests for uranium: 90.
Extraction Processes—
General: 90.
United States
General—
Bibliography of U.S.G.S. reports: 572.

URANIUM PROSPECTING

See Uranium Exploration and Geophysical Exploration.

URANOCIRCITE OCCURRENCES

South Dakota
General: 592.
Lawrence County—
Black Hills, northern part: as an accessory mineral in siliceous gold ores; location not named: 621.
Pennington County—
Black Hills, northern part: as an accessory mineral in siliceous gold ores; location not named: 621.
Keystone: 78, 82.

URANOPHANE OCCURRENCES

South Dakota
Pennington County—
Black Hills—
Ingersoll claim: some alteration of uraninite to gummite and uranophane: 576.

V–Y

YTTRIALITE OCCURRENCES

Texas
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Z

ZEUNERITE OCCURRENCES

South Dakota
Pennington County—
Poisoned Ox mine near Pactola: 617.

ZIRCON MINERALOGY

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Chemical analyses: Oklahoma samples: 595.
Spectrographic analyses: Oklahoma samples: 595.
X-ray patterns: Oklahoma samples: 595.

ZIRCON, THORIUM-BEARING

Oklahoma
Comanche County—
Quanah granite in Quanah Mountain in Wichita Mts.: uranium and thorium in metamict and fresh zircon in pegmatite: 595.

ZIRCON, URANIUM-BEARING

Oklahoma
Comanche County—
Quanah granite in Quanah Mountain in Wichita Mts.: uranium and thorium in metamict and fresh zircon in pegmatite: 595.

U.S. Atomic Energy Commission, Div. of Raw Materials, New York, N. Y.

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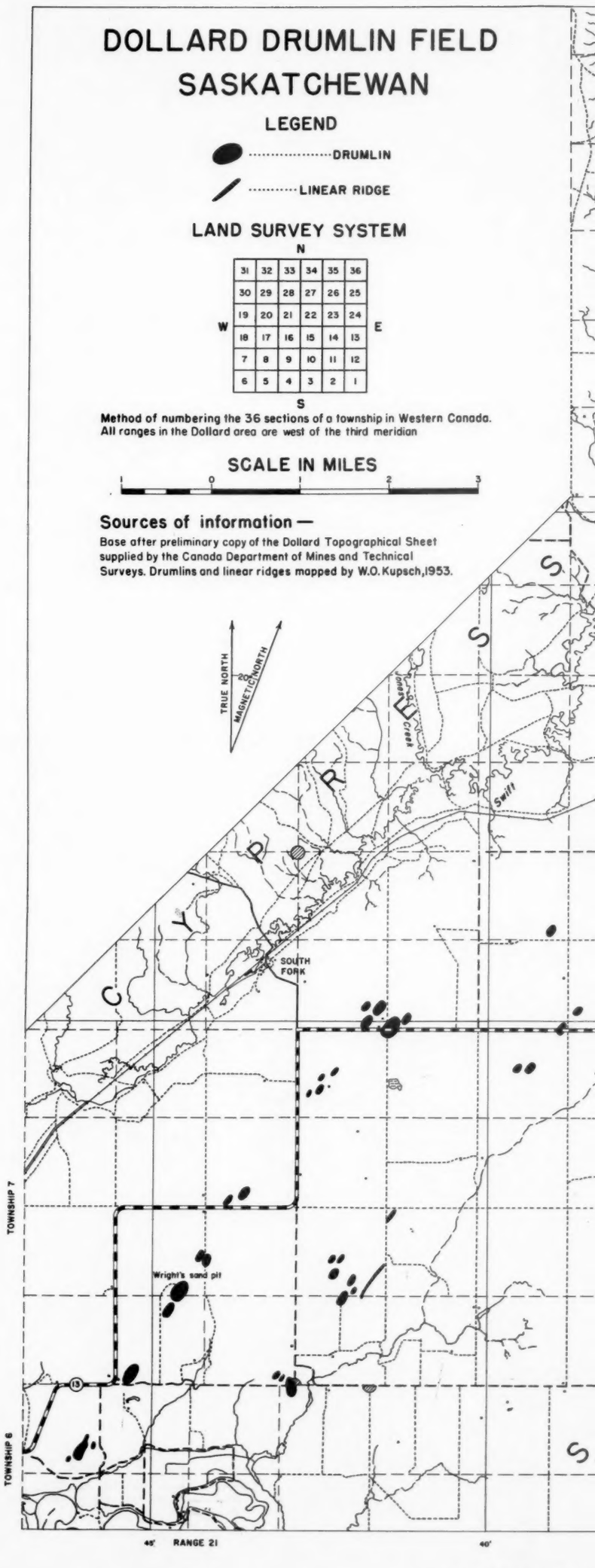
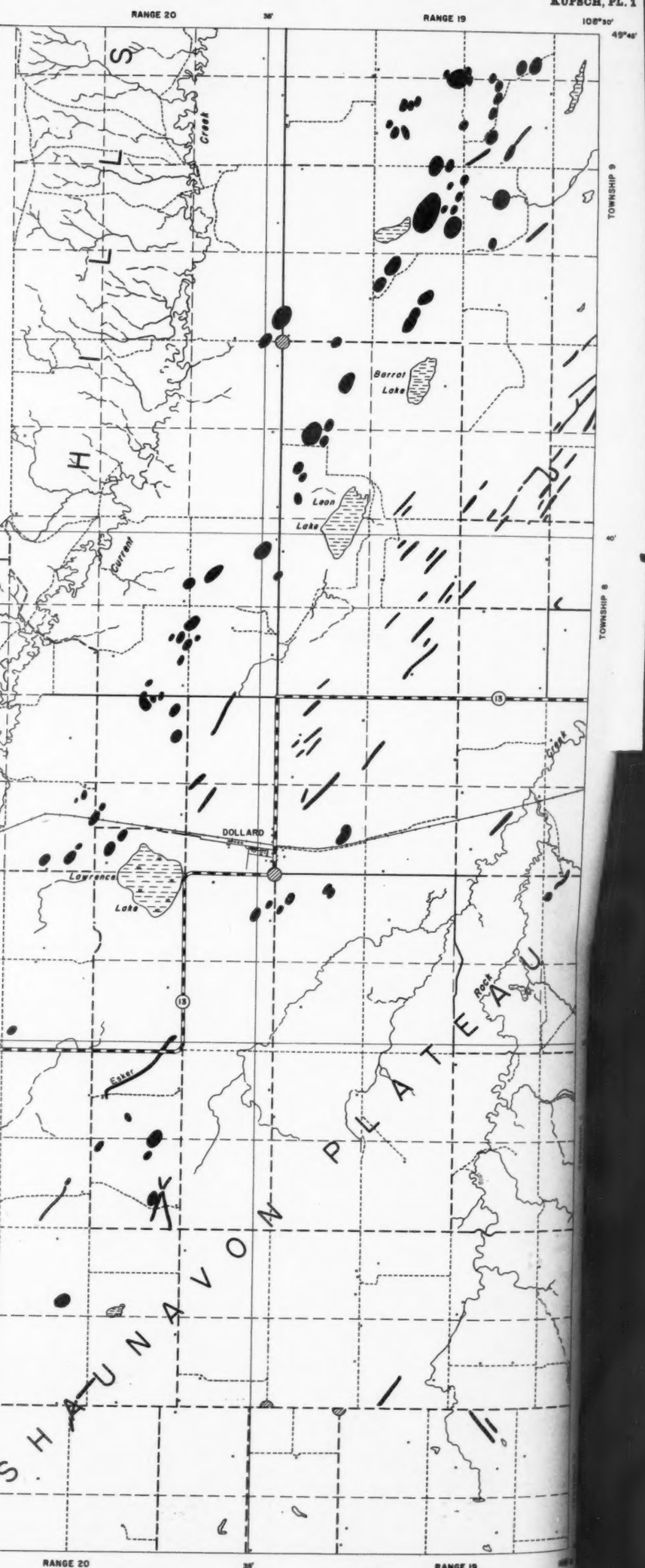
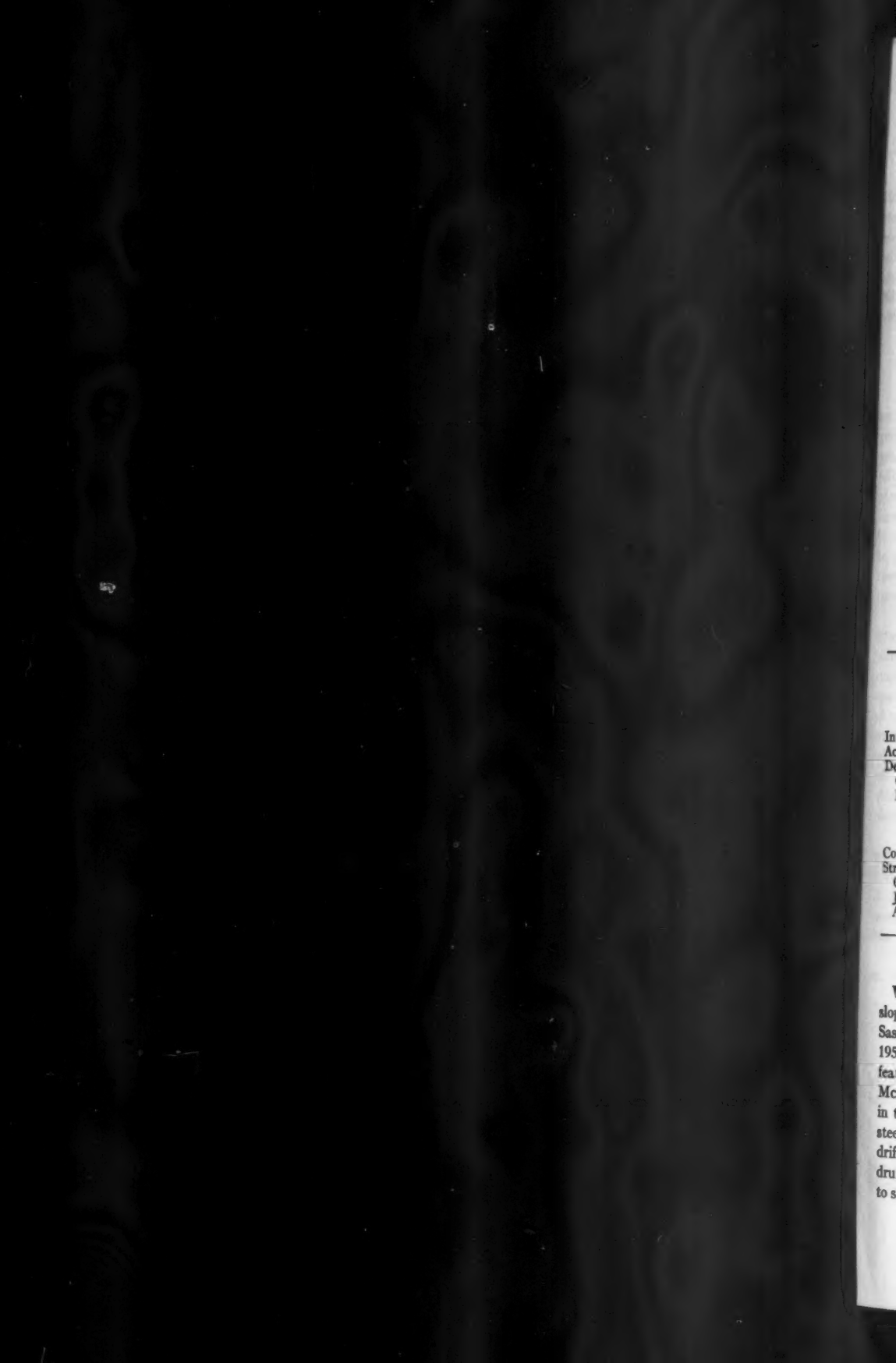

DOLLARD DRUMLIN FIELD
SASKATCHEWAN
LEGEND
DRUMLIN
LINEAR RIDGE
LAND SURVEY SYSTEM
N
31 32 33 34 35 36
30 29 28 27 26 25
19 20 21 22 23 24
18 17 16 15 14 13
7 8 9 10 11 12
6 5 4 3 2 1
W
E
S
Method of numbering the 36 sections of a township in Western Canada.
All ranges in the Dollard area are west of the third meridian
SCALE IN MILES
0
2
3
Sources of information —
Base after preliminary copy of the Dollard Topographical Sheet supplied by the Canada Department of Mines and Technical Surveys. Drumlins and linear ridges mapped by W.O. Kupsch, 1953.
TRUE NORTH
MAGNETIC NORTH
SOUTH FORK
Swift Creek
Wright's sand pit
TOWNSHIP 7
TOWNSHIP 6
RANGE 21



FIELD, SASKATCHEWAN



BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
VOL. 66, PP. 327-338, 6 FIGS. 2 PLS. MARCH 1955

DRUMLINS WITH JOINTED BOULDERS NEAR DOLLARD, SASKATCHEWAN

BY W. O. KUPSCH

ABSTRACT

The drumlins in the Dollard area, Saskatchewan, are short streamlined hills, composed of stratified drift and till. Some of these drumlins are believed to represent former kames overridden by the ice. Extensive exposures of one drumlin reveal its internal stratigraphy and structure. The frontal part, facing the direction of ice movement, consists of stratified sand and gravel. The tail probably consists of till, with minor intercalations of gravel. Separating these two parts is a vertical wall of stratified drift consisting of large boulders, cobbles, and pebbles in a matrix of coarse sand. The boulders in this wall have fractures which can be considered joints as they are arranged in a well-oriented system. Analysis of the joints shows two sets of shear joints and one of extension joints. Boulders of dolomite and limestone have both extension joints and shear joints; boulders of granite have shear joints only. The joint pattern indicates that a simple compressive force acted on the wall in the drumlin which was confined above and below. The direction of this force was parallel to that of the ice movement as indicated by the long axis of the drumlin. The joints are, therefore, interpreted to be the result of pressure by moving ice against the frontal part of the drumlin.

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INTRODUCTION

While studying the geology of the eastern slope of the Cypress Hills in southwestern Saskatchewan during the summers of 1953 and 1954, the writer investigated some glacial features in the neighborhood of Dollard. McConnell (1886, p. 12C) described the plain in this area as "dotted at intervals with small steep-sided conical hills built apparently of drift." These landforms are here called drumlins. Only a few are well enough exposed to show the internal composition and structure. Some are apparently composed of till alone, whereas others are composed of till and stratified sand and boulders. Those containing stratified drift may be considered kames by some, but the streamlined form and the structure of at least two of these hills indicate that they were shaped by actively moving ice, which would make the term "drumlin" more appropriate than "kame." The postulated origin is that of "drumlinized kames."

Plate 1 shows the location of the drumlins studied, all of which lie within the boundaries

follows (Ebers, 1926, p. 176–177): (1) mamillary, with a length to width ratio of three to one or less, (2) lenticular, with a length to width ratio of more than three to one but less than five to one, and (3) elongated, with a length to width ratio of more than five to one. The drumlins of the Dollard field are elliptical to subcircular in plan. Their length ranges from 250 to 2500 feet and their width from 75 to 1000 feet. Their average dimensions, as determined by an air photo analysis of 98 drumlins, are 750 feet long and 350 feet wide, and so their length to width ratio is approximately two and a half to one, well within the mamillary class. Deviations from this average are slight; only three drumlins have a length to width ratio slightly higher than three to one.

The height of the drumlins nowhere exceeds 150 feet, and most are not over 75 feet high, the smaller ones being only 20–40 feet high. Slopes as much as 30°, but generally 15°–20°, were observed for the stoss side, whereas the lee side showed slopes as low as 6°. In contrast to the asymmetrical longitudinal profile, the transverse profile is commonly symmetrical except for composite forms consisting of a single large drumlin with several smaller ones on its side. A good example of a composite drumlin is in sec. 33, T. 6, R. 21, W. 3rd mer. It is composed of at least four streamlined elements. The long axes of the drumlins have an average strike[1] of 30°, which represents the approximate direction of last movement of the glacier across the area.

Linear ridges.—Short linear ridges are present in some parts of the drumlin field. They are concentrated within township 8, range 19, west of the third meridian (Pl. 1). Twenty-six well-developed ridges, measured on air photos, have an average length of 1350 feet and an average width of 120 feet. The length to width ratio is therefore 11.7 to 1. The height of the ridges is not more than 20 feet and most are only a few feet high. The average strike of the long axes of the ridges is 45°, a deviation of about 15° from that of the drumlins.

Most of the ridges are remarkably straight. The few bends are angular rather than gentle curves. A most outstanding example of such an angular bend is that of a ridge in sec. 28, T. 8, R. 19, W. 3rd mer.

Lack of adequate exposures makes a study of their internal composition impossible, but the surface material indicates that most ridges are composed of till.

The ridges are interpreted as longitudinal crevasse fillings. Their straightness, angular bends, relative shortness, and occurrence in swarms indicate that they are not typical eskers which are commonly longer, more sinuous ridges. Some air photos show a suggestion of a second system of ridges, perpendicular to the first and transverse to the direction of ice movement. This second system, however, is so poorly developed that only in a few places it was definite enough to be shown on Plate 1.

Composition of Ground Moraine

The ground moraine of the Dollard drumlin field consists of till composed of yellow to bluish-gray, silty clay with few boulders and some irregular pockets of sand and gravel. Most of the finer material is derived from the underlying Upper Cretaceous formations; the coarser material is derived from Precambrian and Paleozoic outcrops in northern Saskatchewan, at least 400 miles to the north. The drumlins are found only in an area underlain by the predominantly sandy Upper Cretaceous Eastend and Frenchman formations. They are conspicuously absent where the shales of the Bearpaw underlie the drift.

The thickness of the drift as determined from water well data (MacKay *et al.*, 1936a; 1936b) ranges from a few feet to a maximum of 65 feet. It seems to be thicker in the northeast part of the area than in the southwest. Although well data from some drumlins show the drift to be only 20 feet thick, there is no reason to believe that till is absent beneath some drumlins or that some may have cores of rock as has been reported from other fields. The relatively thin drift in the Dollard area indicates that a thick drift cover is not prerequisite for the formation of drumlins.

Since exposures of the drumlins are few in the Dollard area, the composition of most drumlins is unknown. Some are apparently composed entirely of till (NE.¼ sec. 3, T. 9, R. 20, W. 3rd mer.), others of till and stratified material.

[1] All bearings are given in degrees azimuth.

Structure of a Drumlin

General Remarks

In S.E.¼ sec. 11, T. 7, R. 21, W. 3rd mer. a large part of a drumlin with its structure well preserved is exposed in a sandpit owned by Mr. F. E. Wright of Eastend, Sask. On a line with it, several hundred feet southwest, a second drumlin is exposed with internal structures similar to those observable in Wright's sandpit but not as well exposed.

The Wright drumlin stands about 60 feet above the surrounding plain (Fig. 1). The length is 1600 feet, the width 1100 feet, and the long axis trends 33°. The northeast flank slopes 10° near its base and 25° near the crest. The tail slopes at a minimum of 5°. In all these characteristics, this drumlin is similar to the majority of forms in the Dollard field. On the west flank, a small drumlin is superimposed on the larger one, but this irregularity is clearly visible in the field and the major part is undoubtedly one simple drumlin.

The frontal third of the drumlin consists of stratified coarse sand and gravel in which crossbedding is common. Most of this material has been removed, so that it is no longer possible to determine the structure of the beds. The remaining portion, however, shows some structures characteristic of ice-contact material. The beds as a whole seem to have been tilted. Glacio-fluvial intercalations in the frontal part of drumlins are common in many other fields and generally show deformation of the strata (Ebers, 1926, p. 222).

The distal two-thirds of the drumlin appears to be composed of till consisting of unstratified sandy clay with a few boulders, as indicated by exposures in several shallow pits and 12 foot-deep bore-holes. Overlying the whole drumlin is several feet of sandy till with some pebbles and boulders (Fig. 1).

Jointed Boulders

A wall of boulders, containing small amounts of interstitial coarse sand and gravel, separates the frontal stratified part of the drumlin from the unstratified tail. This wall, exposed in the southeastern and northwestern parts of the sand pit, is approximately perpendicular to the long axis of the drumlin and about 30 feet high in the central part. Boulders 1 foot in diameter are common and several have a maximum diameter of 3 feet. All boulders seem to be derived from northern Saskatchewan. They show some degree of rounding and are clearly water worn.

A remarkable feature of this wall of boulders is the presence and relationship of fractures in many of the boulders (Pl. 2, fig. 2). To these well-oriented fractures the name "joints" can be applied as they form a system of three sets, are relatively straight and persistent, and show no displacement in relation to the plane of fracture, except for some gravitational slipping in places. The joints cut boulders of a variety of lithologic types and the relative abundance of fracture boulders is as follows:

	Per cent
A. Granite and granite gneiss, granodiorite, and pegmatite	41
B. Limestone and dolomite	29
C. Various schists and gneisses (other than granite gneiss)	19
D. Volcanic rocks	6
E. Sandstone and quartzite	5

The jointing occurs not only on the surface but also through the thickness of the wall as shown by excavation. In general, there are only one or two fractures in the granite boulders, but a set of many joints or even several sets may be present in those of dolomite. In a few places, it is possible to trace the same joint from one boulder into a subjacent boulder. Such persistent joints may cut through unrelated rocks such as granite and basic volcanic or granite and garnet gneiss. The joints are best developed in stones of boulder size but they also occur in some particles as small as one inch in diameter, that are part of the matrix.

Most of the joints are vertical or steeply dipping. Plotting of the attitudes of 300 joints on a rose diagram (Fig. 2) and on a point diagram (Fig. 3) reveals some additional characteristics. The rose or strike diagram shows three preferred orientations of the joints, indicative of three joint sets. The most pronounced has a direction ranging from 335° to 20°. The average orientation is 355°. The second set ranging from 75° to 100°, is less pronounced and has an average orientation of 92°. It is therefore approximately perpendicular to the

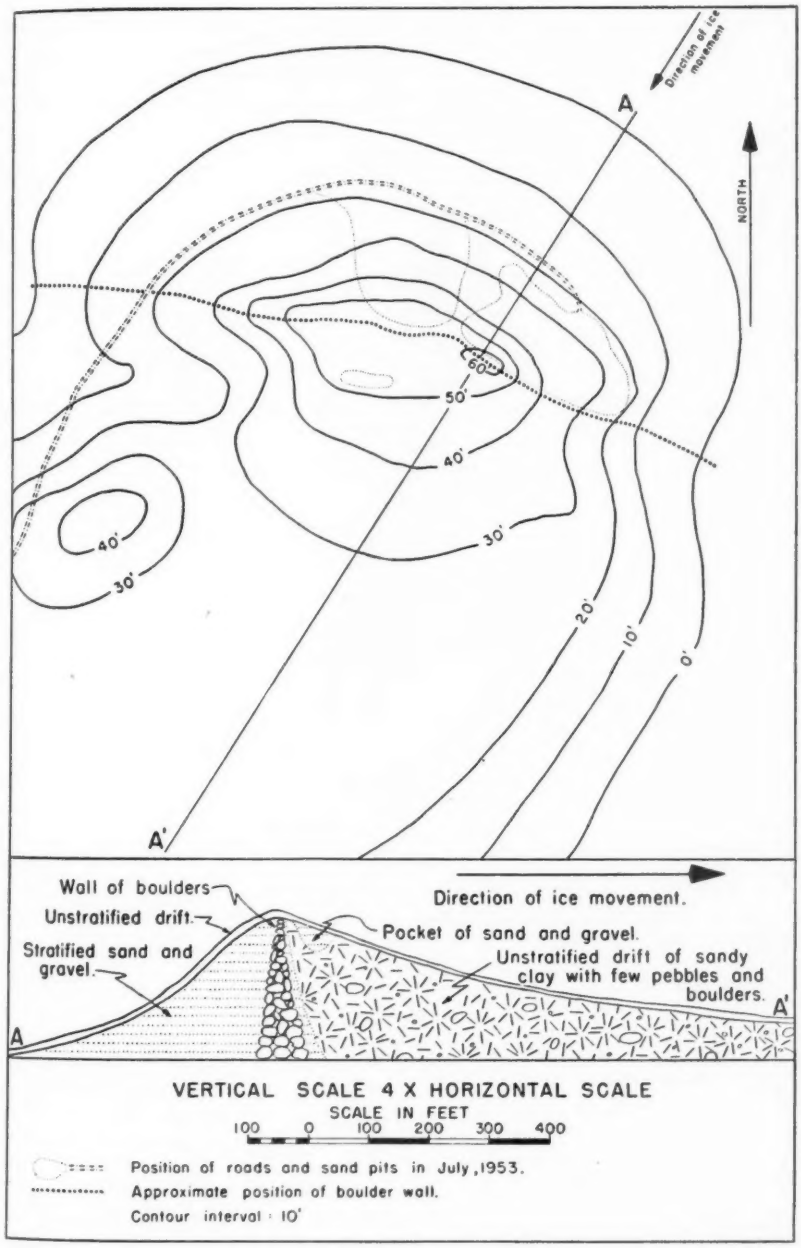

FIGURE 1.—WRIGHT'S SAND PIT

Map and profile of part of the drumlin in S.E. ¼ sec. 11, T. 7, R. 21, W. 3rd mer. Positions of the sand pits in the frontal part of the drumlin are indicated on the map. Contours have been restored over the pits.

first set. The third set ranges from 25° to 40°, and its average orientation is 34°. It is well defined, although it contains fewer joints than the other two sets.

on the top and on the bottom, only two sets of shear fractures will form, parallel to the planes ABCD and EFG. These two sets are approximately perpendicular to each other and at an

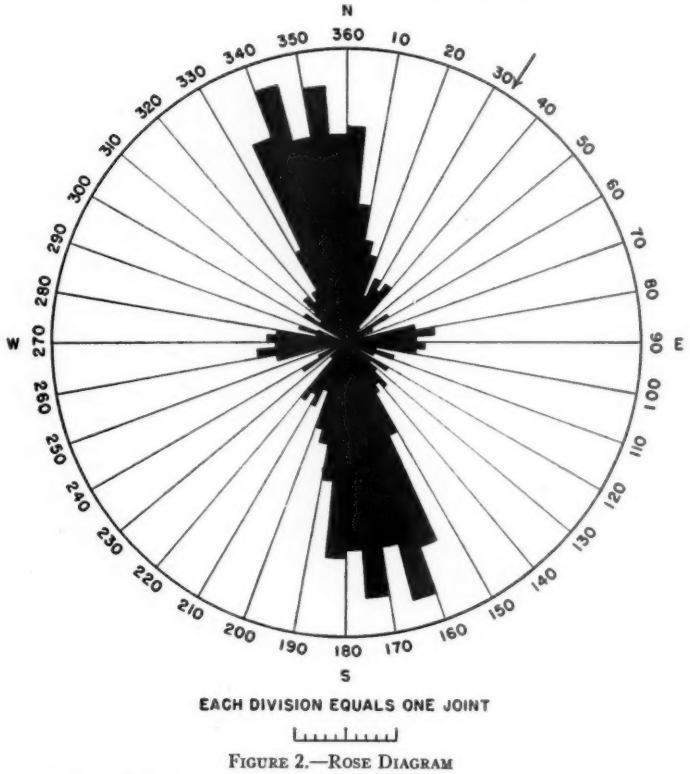

FIGURE 2.—ROSE DIAGRAM

Rose diagram showing strike of joints in boulders in wall at Wright's sand pit. Small arrow at 33° indicates direction of long axis of drumlin.

Analysis of Joint System

The joint system is interpreted as ruptures developed in response to a simple compressional stress that exceeded the elastic limit of the boulders. Comparable failures were made experimentally by subjecting a brittle test specimen to a compressive force (Billings, 1946, p. 101–103). Figure 4 shows the sets of fractures that develop in such a test prism. If the four sides of the specimen are free to expand outward, four sets of shear fractures will develop. These are parallel to the planes ABCD, EFG, HIJ, and KLMN. If the test prism is confined angle of 45° to the compressive force. Commonly one of the two sets of shear fractures is much better developed than the other.

Other failures which develop in test specimens under simple compression are extension fractures parallel to the sides of the prism. Two sets of these develop when all sides of the prism are unconfined, whereas only one develops (parallel to plane OPQ in Fig. 4) when the top and the bottom of the specimen are confined. A single test specimen develops extension fractures or shear fractures, but not both. In Figure 4, both types of failure are shown in the same prism to simplify presentation.

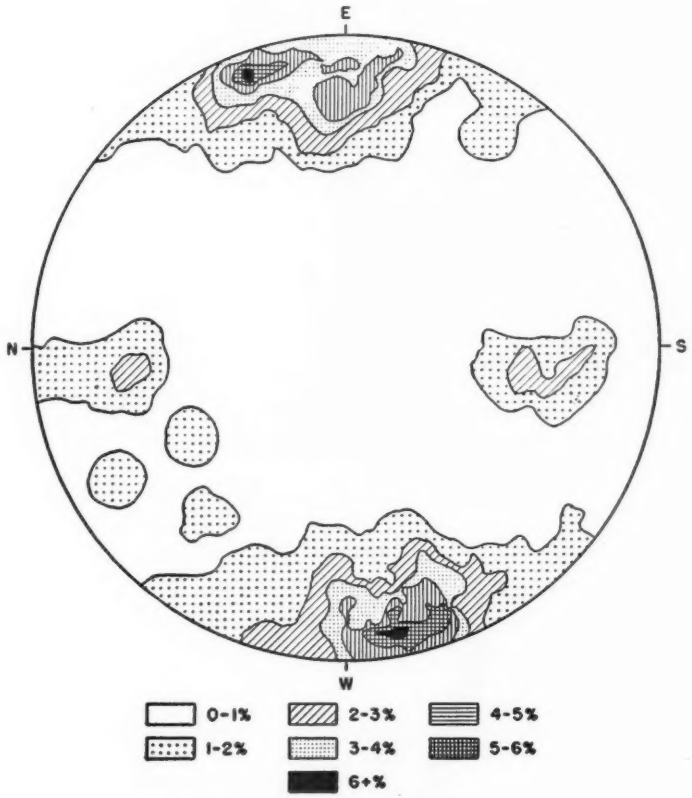

FIGURE 3.—POINT DIAGRAM

Point diagram showing poles of perpendiculars to 300 joint surfaces plotted on an upper hemisphere. Equal area projection. To orient the maxima in Figures 2 and 3 in the same direction, the point diagram was rotated 90° counterclockwise.

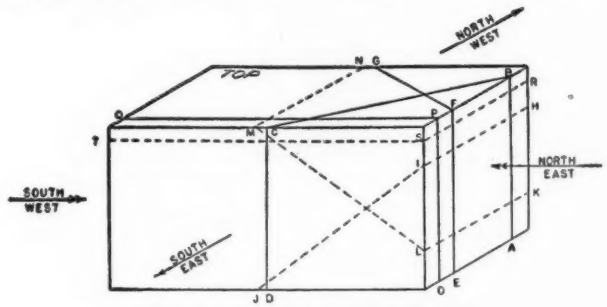

FIGURE 4.—FAILURE OF TEST SPECIMEN

Modified after Billings, 1946. For easy comparison the test specimen has been oriented approximately the same as the wall in Wright's sand pit. The test specimen is subjected to simple compression. Ruptures shown by broken lines do not develop when the test specimen is confined on top and bottom with lateral expansion possible. Planes ABCD, EFG, HIJ, KLMN are shear fractures; planes OPQ and RST are extension fractures.

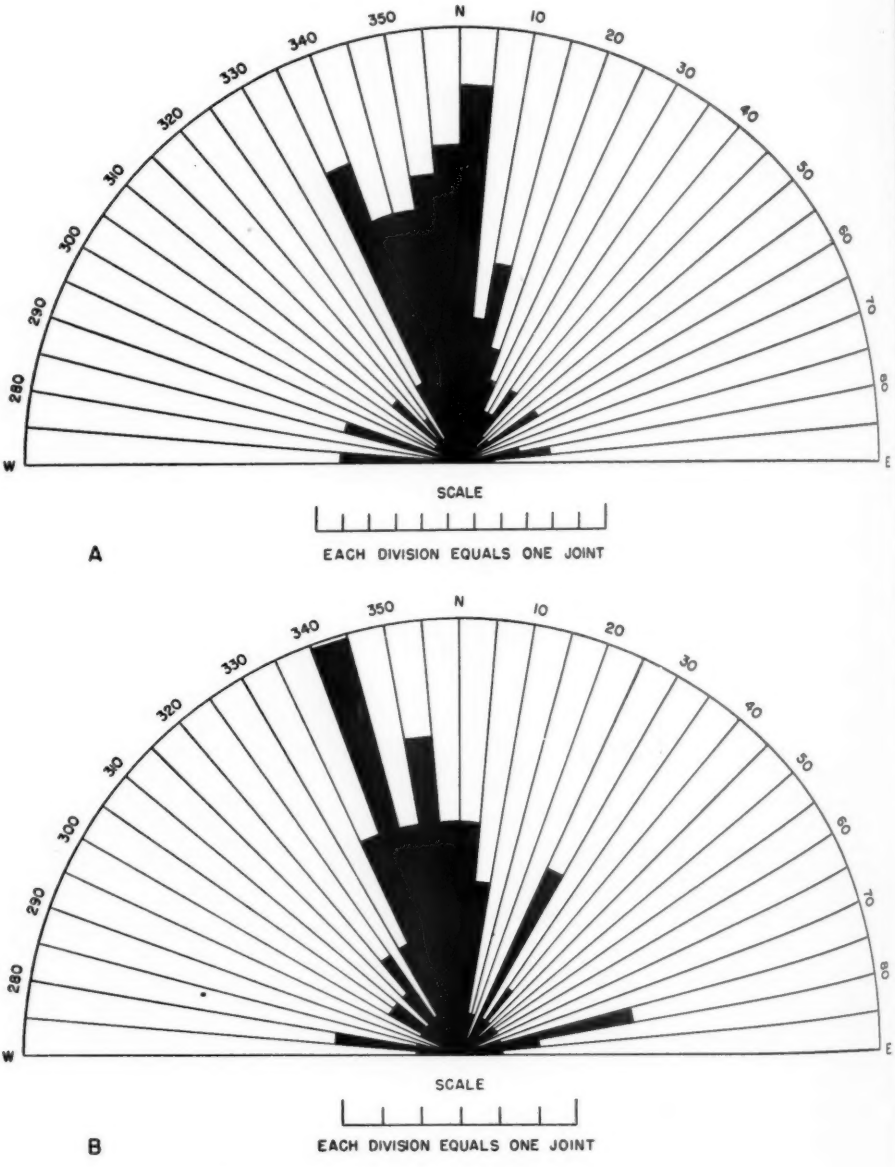

FIGURE 5.—RELATION OF JOINT ORIENTATION TO ROCK TYPE

A. Orientation of joints in boulders of granite, granite gneiss, granodiorite, and pegmatite.

B. Orientation of joints in boulders of limestone and dolomite. Notice concentration of joints in 25°–30° range. Because limestones and dolomites comprise about 30% of total number of boulders, and granites, etc. about 40%, scale of diagram B has been made 1.3 times as large as that of diagram A for comparison.

Comparison of the fracture system in the test specimen with that in the boulders in Wright's sand pit shows that the sets of joints in the wall striking 355° and 92° are shear joints. The set at 355° is more intensely developed than that at 92°. The absence of additional sets of shear joints suggests that lateral relief was available, whereas top and bottom of the drumlin were confined. These conditions are not universal. Lateral pressure is shown by contorted beds in a transverse section of one of the drumlins of Wisconsin (Alden, 1905, p. 31). Some transverse sections through drumlins on the south shore of Lake Ontario indicate that locally lateral pressure on one flank was greater than that on the other (Slater, 1929, p. 18).

The third set of joints, striking at 34°, presumably consists of extension joints. As shown in Fig. 5, boulders of dolomite and limestone are more susceptible to extension jointing than those of granite, granodiorite, granite gneiss, and pegmatite in which this type of rupture is rare. It should be noted, however, that even in boulders of dolomite and limestone, shear joints are the most abundant type of failure with extension joints second.

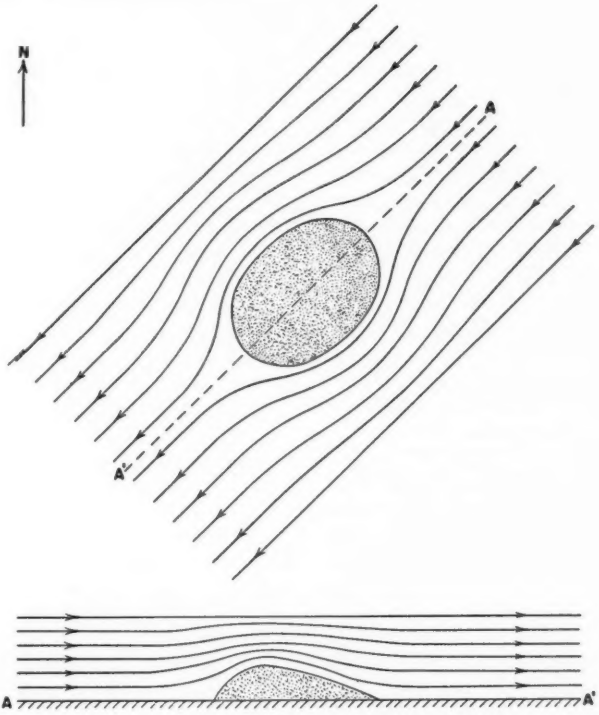

FIGURE 6.—FLOW OF ICE AROUND DRUMLIN

The joint system suggests that the wall of boulders and the frontal part of the drumlin were overridden by actively moving ice. The joint pattern in the boulders resulting from this movement is analogous to the pattern of test specimens. Any deviations from the theoretical pattern expected in brittle substances under simple compression with lateral relief, are probably due to the inhomogeneity of the wall of boulders and to possible variations in the direction of the compressional force. Such deviations are indicated by the angle between the two shear directions and the position of the

set of extension joints. The angle between the two shear directions cannot be determined exactly but it appears to be somewhat larger than the 90° expected on theoretical grounds. The extension joints strike at about 34°, which is the direction of ice movement across the drumlin as indicated by the trend of its long axis (33°), but which is not the bisector of the two theoretical shear directions. The 33-degree direction of ice movements represents an average for the whole drumlin. The western part of the drumlin was presumably affected by a more easterly compressive force and the eastern part by a more westerly force. This is clear from the direction of flow lines of ice moving around and over a drumlin as shown in Figure 6. Of the 300 joints measured in the boulders, 200 were observed in the most easterly pit and the other 100 in the western pit. When the data for these two pits are considered separately, it appears that the major shear joints strike more to the east in the western pit than in the eastern pit.

The joint pattern indicates more lateral than vertical relief from the compressional force. Figure 6 shows that this is to be expected. The horizontal flow lines of the ice bend outward to either side of the drumlin, but the vertical relief, as shown in the profile, is only upward and considerably less than the lateral relief to one side as the height of the drumlin is less than half the width.

Origin of the Dollard Drumlins

It is postulated that for a time during the last glaciation covering the area, the ice was stagnant. The ice edge thinned and became brittle, and crevasses formed which were open to the bottom of the ice. Some of the crevasses were straight longitudinal cracks and the deposits in them formed the longitudinal linear ridges. Till was probably the most common material deposited, but in some crevasses the removal of finer-grade sizes by meltwater may have resulted in the accumulation of sand and gravel. Other openings in the ice were wider and more irregular. In them irregular mounds of stratified drift were deposited, forming kames. Other kames may have formed at the ice edge as outwash cones (Flint, 1947, p. 148).

The frontal stratified part of Wright's drumlin shows features peculiar to ice-contact material and is believed to represent a kame. Sorting of the material took place by meltwater and the coarsest material was concentrated along the southwest wall.

A period of actively moving ice followed the temporary halt, and crevasses near the bottom were closed. The kames probably became solid blocks as the water in them froze. The flow of ice encountered these rigid nuclei of stratified drift and abraded their stoss ends into a streamlined form, at the same time fracturing the boulders. In the Wright drumlin, stresses transmitted through the solid mass of ice and sand caused a system of joints in the coarser material on the southwest side, but did not much affect the finer material in the front. On the lee side of the nucleus, some of the material was removed by the ice. The different processes on the stoss and the lee side shaped the nucleus of stratified drift to resemble a *roche moutonnée* having a steeper lee side than stoss side. In the lee of this reshaped nucleus, till was deposited forming a tail behind the obstruction. The drumlin formed thus consists of two parts: one frontal part essentially erosional, having the shape of a *roche mountonnée*, and one distal part essentially depositional, forming the gently sloping tail. Upon the final melting of the ice, the whole area became covered with a layer of ablation till of varying thickness.

This theory of origin follows in many respects previous explanations of drumlin formation, recently reviewed by Gravenor (1953, p. 674–681). A similar origin has been assumed for some drumlins possessing a solid rock core, such as those in the Boston, Massachusetts, area. In drumlins composed entirely of unstratified drift, it may be difficult to separate the nucleus from the tail, although it is possible to do so in favorable circumstances (Slater, 1929).

According to this concept, *roches moutonnées*, crag and tail, rock drumlins, drumlins with stratified drift cores, and drumlins with till cores would form one series, all composed of modified nuclei with no, a little, or much glacial material lodged on their lee side. The amount would depend on the load of the ice and its

velocity. How the ice erodes or quarries the lee sides of obstructions remains unanswered.

Although it is not possible to determine exactly the thickness of the ice at the time of formation of the drumlins, it is possible to estimate the maximum thickness. The Cypress Hills, forming a nunatak above the ice about 50 miles west of the Dollard area, show no signs of glaciation above an altitude of 4400 feet (McConnell, 1886, p. 75). Assuming no post-glacial differential movements between the Dollard area and the higher parts of the Cypress Hills and no slope of the surface of the ice between the two areas, the maximum thickness of the ice was about 1300 feet, as the drift in the Dollard area is at an altitude of approximately 3100 feet. It is likely that the thickness of the ice was less than the maximum during deposition of the glacio-fluvial material presumably accumulated during stagnation by meltwater in open crevasses, which are believed to extend to the bottom only if the thickness of the ice does not exceed 200 feet (Flint, 1947, p. 17).

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Short Notes

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UNUSUAL DESICCATION CRACKS IN THE BENWOOD LIMESTONE OF EASTERN OHIO

By J. A. Fagerstrom

The relatively unweathered highwalls of a great number of extensive strip mines offer unusual opportunities to study in great detail the stratigraphy and primary sedimentary structures of the rocks of the Monongahela Series (Upper Pennsylvanian) in eastern Ohio. This paper describes and interprets some unusually large desiccation cracks exposed on these highwalls in Short Creek Township, Harrison County, Ohio, approximately 20 miles northwest of Wheeling, West Virginia, and 25 miles southwest of Steubenville, Ohio. These cracks occur in the Benwood limestone which is stratigraphically 13 feet above the Meigs Creek (Sewickley) coal, 106 feet above the Pittsburgh coal, and 78 feet below the Waynesburg coal.

Description

Throughout this area the Benwood is uniform in appearance. It consists mainly of medium-gray, fine-grained argillaceous limestone 30–35 feet thick. There are lesser amounts of gray to tan claystone and siltstone in both the upper and lower 5–10 feet of the formation. The large desiccation cracks are restricted to one massive, unbedded layer of limestone 8–10 feet thick located in about the middle of the formation (Pl. 1, fig. 1). The cracks penetrate the entire thickness of this layer and end sharply at its upper and lower contacts. In general the cracks are vertical, but a few are offset horizontally by as much as 6 inches, while others bifurcate in the lower 3–4 feet. Since the highwalls have weathered so that the cracks are recessed 1–2 feet from the adjacent limestone, each crack appears to have a definite trend or "strike." These "strikes" measured on the flat surfaces between the limestone and the material filling the cracks (as, for example, the left-hand contact of the crack in Pl. 2, fig. 2) are randomly oriented and fall into a system indicating that the cracks bound polygonal bodies of rock in plan view (Pl. 1, fig. 3). If these are true polygons the spacing of the cracks in Figure 1 of Plate 1 shows that they are at least 6 or 8 feet in diameter.

The contacts between the adjacent limestone and the filling material are sharp and even from top to bottom. In cross section the cracks are V-shaped, narrowing downward from a maximum width of 10 inches to less than 1 inch.

The cracks are filled with vertically bedded, tan to brown shale (Pl. 1, fig. 2) and siltstone. The beds of shale are from a sixteenth of an inch to an inch thick, and each bed has constant thickness. The outer shale beds, however, are variable in thickness and conform to the irregularities in the contact with the limestone. There is no evidence of horizontal bedding or lamination in the shale.

Interpretation

Cracks of this nature have been variously described and interpreted as "ice cracks," clastic dikes, faults, joints, or unusual weathering of pre-existing fissures. None of these explanations applies to the cracks of the Benwood.

They are not "ice cracks" because the walls show no evidence of having been forced apart by freezing water. They are not clastic dikes because the filling shows no evidence of having been intruded into the cracks under pressure. The fact that the cracks narrow toward the

base indicates that the filling was not forced up from stratigraphically below the Benwood. The cracks are not faults or joints because they are restricted to one layer and do not penetrate the subjacent beds, they have no fault or joint system, and there are no tectonic features of this type in the area.

The cracks owe their present appearance in part to recent weathering by running water flowing over the highwalls. However, abundant evidence indicates that the cracks were formed prior to the exposing of the Benwood for stripping operations. It seems fairly certain that the cracks are now recessed from the adjacent rock because rain water has flowed over the highwalls and has been concentrated in channels in the cracks thus enlarging and deepening them. The fact that the cracks narrow toward the base whereas most stream channels widen in the direction of flow indicates that the cracks do not owe their origin and V-shaped profile to recent weathering. Furthermore, since the cracks are restricted to one layer and are horizontally offset and bifurcate toward the base, they must pre-date the stripping. The runoff has simply followed the less resistant cracks in this layer and enlarged them to their present form.

The weight of evidence supports the hypothesis that these are true desiccation cracks developed on a larger scale than is commonly believed possible. However, some facts are difficult to explain. In support of the hypothesis is their V-shaped cross section, sharp contacts with the overlying and underlying rock and with the adjacent wall rock, and the fact that they appear to surround polygonal bodies of rock lithologically suitable for the development of desiccation cracks. In addition Gilbert (1877, p. 9) has described "sun-cracks" 3 meters deep in the Shinarump shale of Utah. There is no evidence of curling of the upper layers of the limestone adjacent to the cracks. It is also difficult to account for the absence of horizontal bedding in the filling. The former is not a serious objection since Twenhofel (1926, p. 494) says that the edges of some cracks remain flat upon drying.

The following explanation of the origin of the vertical bedding in the filling material is entirely theoretical. However, it is plausible and possible. After the cracks had developed from drying in an arid climate they were filled by uninterrupted deposition of silt and clay. Later the area was submerged, and the overlying sediments deposited. Then followed a period of slight tectonic activity during which minor folds such as the Cadiz anticline (Bownocker, 1903, p. 227) developed. This tectonic activity compressed the material filling the cracks caused by minor lateral pressures, giving it the vertical bedding. This compression is analogous to the compression of the jaws of a rock crusher acting upon the V-shaped desiccation cracks.

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713 Oxford Rd., Ypsilanti, Mich.

Plate 1.—DESICCATION CRACKS IN BENWOOD LIMESTONE

Figure 1.—General View of a Highwall

Excavated by the Hanna Coal Co., SE¼ of SW¼, Sec. 25, Short Creek Twp., Harrison Co., Ohio, showing the prominent desiccation cracks in the Benwood limestone

Figure 2.—Close-Up of One Desiccation Crack on a Highwall

NW¼ of SE¼ Sec. 26, Short Creek Twp., Harrison Co., Ohio. Note the vertical bedding in the shale. (Scale 7 inches long)

Figure 3.—View of a Highwall Excavated by the Hanna Coal Co.

NW¼ of SE¼, Sec. 26, Short Creek Twp., Harrison Co., Ohio, showing the random orientation of the desiccation cracks.

FIGURE 1

FIGURE 2

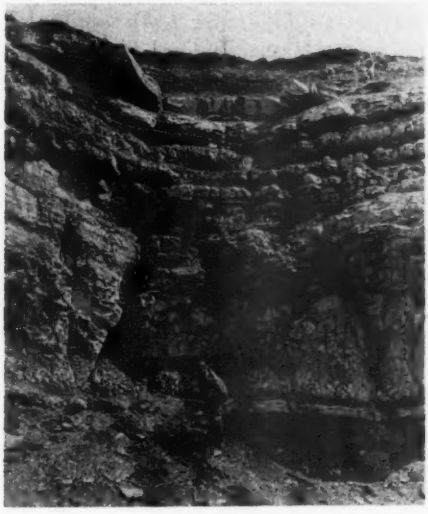

FIGURE 3

DESICCATION CRACKS IN BENWOOD LIMESTONE

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VOL. 66, PP. 341-344, 1 FIG., 1 PL. MARCH 1955

LATE KEWEENAWAN OR EARLY CAMBRIAN GLACIATION IN UPPER MICHIGAN

BY RAYMOND C. MURRAY

GENERAL STATEMENT

Striations, gouges, grooves, and polishing and friction cracks are present on the upper surface of the Michigamme slate where it is unconformably overlain by the Jacobsville sandstone west of L'Anse, Michigan (Fig. 1). These features and their stratigraphic position suggest glaciation in Upper Michigan in the late Precambrian or early Cambrian. No such glaciation has been reported previously from this area and this time. There may be a correlation between this possible glacial event and that in Utah described by Blackwelder (1932). This was also a time of extensive glaciation in Africa and Australia (Coleman, 1926, p. 212), and around the North Atlantic (Kulling, 1951).

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LOCATION

The angular unconformity between the Michigamme slate and the Jacobsville sandstone is exposed along the southeastern shore of Keweenaw Bay of Lake Superior. The outcrop considered in this paper is about 3 feet above the level of the bay and approximately 100 feet below U. S. Highway 41, one-tenth of a mile west of the west town limits of L'Anse, Michigan. The location on the highway is marked by a large section of Jacobsville sandstone exposed in a road cut.

STRATIGRAPHIC POSITION AND AGE OF THE STRIATED SURFACE

The Michigamme slate is Upper Huronian (Van Hise and Bayley, 1895). In this locality it is dark to light green, dense, and somewhat brittle. It strikes N. 55° W. and dips approximately 25° S. The Jacobsville sandstone and conglomerate overlie the slate in angular unconformity. The Jacobsville traditionally has been considered to be Cambrian (Lane and Seaman, 1907). Recent work, however, by Thwaites (1943) and Oetking (1952, Ph.D. Thesis, Univ. Wis.), indicates that a somewhat earlier age, possibly Late Keweenawan, may be more accurate. This places the age of the unconformity as post Huronian and pre-Upper Keweenawan or Cambrian. The preserved erosion surface on which the striations are found is presumed to approximate more closely the age of the overlying sandstone than that of the slate. The sandstone is red, arkosic, cross-bedded, and is interbedded with conglomerate lenses near the base. Directly above the unconformity is a uniform 1- to 2-inch band of white unindurated clay followed by 12 inches of sandstone. This sandstone is overlain by 4–9 inches of conglomerate with pebbles up to 2 inches in diameter. The conglomerate is followed by 2–3 feet of sandstone. Above this sandstone and the extensive sandstone exposure along the road, the bedrock is obscured by slope rubble. There is no possibility that the Jacobsville above the slate is an erratic or landslide block that has come to rest on a more recent surface. The sandstone at the unconformity and in the road cut is essentially flat-lying. The unconformity where exposed for several hundred feet along the shore is also essentially horizontal.

Features of the Preserved Erosion Surface

The upper surface of the Michigamme slate where exposed by the removal of the overlying sandstone is striated, polished, gouged, grooved, and friction-cracked. Since these features are traceable under the overlying sandstone, they could not have been formed by Pleistocene glaciers (Pl. 1, fig. 1). The strike of the striations ranges from N. 50° E. to N. 90° E. The two common directions are N. 50°–60° E. and N. 80°–90° E. These striations range from a fraction of an inch to approximately 10 inches in length. Most are single, well-defined scratches. A few of the large striations bifurcate to the southwest suggesting that the pebble responsible for the cutting broke into two and continued to cut (Pl. 1, fig. 2). Such bifurcation is considered (Thwaites, 1953, p. 23) as possible evidence that the motion of the pebble making the striations was in the direction of the divergence. In the case of the striations on the Michigamme slate the motion was to the southwest from the northeast.

Friction cracks with fracture planes that dip to the southwest are present. Most of these grade into striations (Pl. 1). Most of these cracks have actual surface depressions that expose the fracture plane. These depressions were apparently formed by chipping off a small piece of rock above the fracture plane at each crack. The removal of these small rock chips produced a mark or concentric gouge concave in the direction of dip of the fracture plane. The dip of the fracture planes to the southwest indicates the motion may have been in this direction (Harris, 1943, p. 244). This southwest motion agrees with the evidence from the bifurcating striations

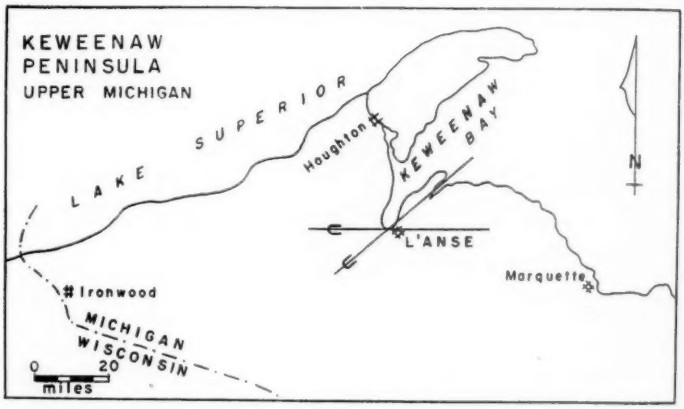

Figure 1.—Location Map Showing Keweenaw Peninsula, Upper Michigan
The two arrows cross at the outcrop and indicate the angular limits of the observed striations.

Origin of the Features

Surfaces of this character may conceivably be produced by mudflows, landslides, Pelean clouds, and other similar mechanisms. No

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Plate 1.—STRIATED EROSION SURFACE BELOW THE JACOBSVILLE SANDSTONE

Figure 1.—Exposed Erosion Surface on the Michigamme Slate
Showing crossed striations and striations going under the overlying Jacobsville sandstone in the upper right. The white clay beneath the Jacobsville can be seen in the lower right.

Figure 2.—Portion of the Erosion Surface on the Michigamme Slate
The friction cracks in the upper right grade into a large striation which bifurcates to the lower left. Note the divergence in the strike of the striations.

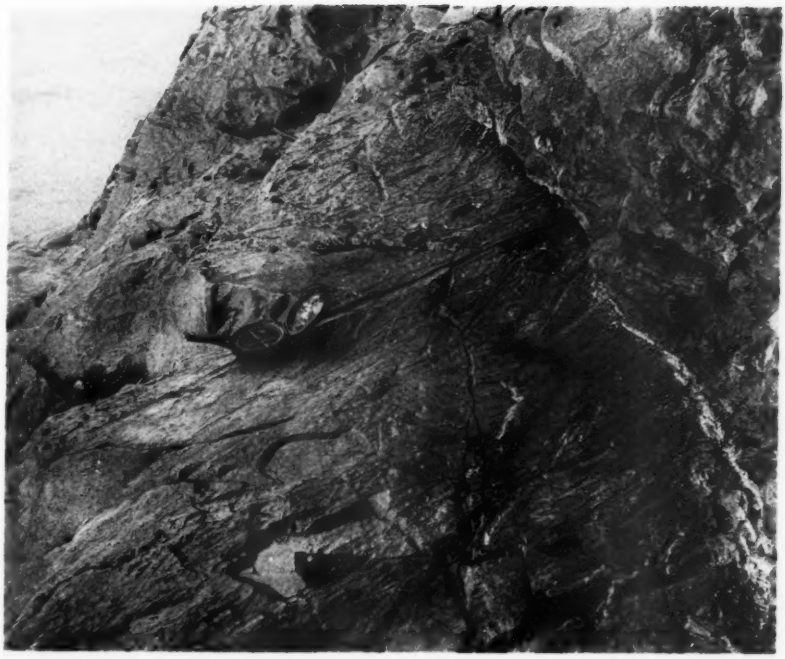

FIGURE 1

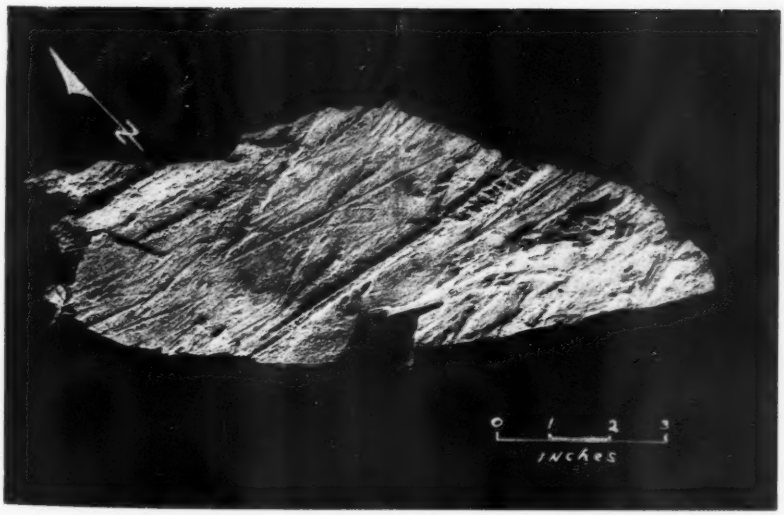

FIGURE 2

STRIATED EROSION SURFACE BELOW THE JACOBSVILLE SANDSTONE

specific evidence for contemporary volcanism or deposition by mass movement is available. The writer believes that either faulting or moving ice is the most reasonable agent for producing this surface.

The following negative evidence does not suggest faulting and thus does not support the hypothesis that the features are slickensides:

(1) The fault must have been horizontal, and the surface of movement must have been the plane of the unconformity. Although this is not uncommon, it is at least a special case. (2) There are no effects of drag, brecciation, sympathetic faulting, cleavage or tension fractures developed in the sandstone. (3) There are no similarly striated surfaces visible lower in the slate. (4) There is no evidence of secondary mineralization along the surface as is common with many slickensides. (5) The sandstone is horizontal and apparently undisturbed. (6) There is no evidence of post-Jacobsville tectonic movement in the immediate area. The nearest disturbed area is that described by Thwaites (1943) at Limestone Mountain 12 miles northwest of L'Anse. Here the Jacobsville and younger formations are locally folded and faulted in a manner resembling a cryptovolcanic structure.

The best evidence for faulting is the 1- to 2-inch band of clay resting on the striated slate surface under the sandstone. This might be considered a gouge produced by faulting of the sandstone against the slate. It is remarkably uniform, white, and unindurated. Detailed study indicates that, despite its plastic character, the clay band contains a large amount of sand-sized quartz grains. It also carries subangular fragments of quartz and Michigamme slate as does the Jacobsville conglomerate. These fragments reach a maximum size of half an inch in the clay. X-ray studies of the clay-sized fraction of this clay band demonstrated a mixture of approximately 80 per cent illite and 20 per cent kaolin-type mineral. These values should be considered only approximate. The lines of quartz are absent. Similar study of the clay-sized fraction of ground Michigamme slate from the striated surface demonstrates a mineralogy of approximately 50 per cent quartz. The remaining 50 per cent is composed of a mineral near muscovite in the series between illite and muscovite and minor amounts of kaolin and montmorillonite-type minerals.

It is seriously doubted if the mechanical grinding of the Jacobsville sandstone and the Michigamme slate by fault action would produce a fine fraction high in illite and barren of quartz. The weathering of the feldspar and micaceous minerals in the Jacobsville sandstone could produce such a clay. This clay could be transported mechanically down through the sandstone by ground water and deposited on the upper surface of the relatively impermeable slate at depth. Ground water moving along this interface might have removed the iron cement from the lower 2 inches of the sandstone and filled the interstices with the clay. The clay band is such a product. It is composed of sand grains and rock fragments similar to the overlying Jacobsville with the intergranular spaces filled with fine clay. Other areas of reduction of the Jacobsville iron cement and the resulting production of white spots and streaks are reported by Oetking (1952, Ph.D. Thesis, Univ. Wis., p.53). A relatively recent origin for this clay is suggested by the fact that it is unindurated and plastic.

The glacial hypothesis is favored by the following evidence:

(1) The striations are individual and well defined. They are separated by areas of polished surface.

(2) The strike of the individual striations ranges as much as 40°. This indicates changes in the direction of movement without obliterating the earlier scratches. This is not common with fault markings which may be " . . . straight- or curved, but they change their direction and attitude as a group so that they are essentially parallel" (Nevin, 1949, p. 131). The cause of cross striations has been discussed in detail by Chamberlin (1888, p. 200).

(3) "Tension cracks have not been recorded in association with slickensides" (Thwaites, 1953, p. 23). This does not mean that they do not exist, but at least they are not common.

(4) These striations maintain essentially the same width throughout and end as abruptly as they begin. A pebble held in a yielding matrix, such as ice, can cut a striation and then be forced up into the ice and be carried on. This is

not so with a tool on a fault surface which must continue to cut until it is worn smooth.

The surface very closely resembles Pleistocene glaciated surfaces on similar rocks. If the stratigraphic position of the surface were not known it would undoubtedly be attributed to Pleistocene glaciation. These striations have the characteristics of "variation in length," "interrupted continuity," and "persistency of direction," used by Chamberlin (1888, p. 224–225) to describe glacial scorings. Lahee (1941, p. 23–33), in discussing the criteria for differentiating marks produced by glacial abrasion from those produced by other agents, considers friction cracks with concentric gouges as products of glacial action; he notes that variations in the strike of scratches are common with glacial features but that slickensides are always notably parallel. No deposits that might be interpreted as till were found. The possibility, however, that the basal beds of the Jacobsville are glacio-fluvial is not unreasonable. The only positive evidence for glaciation is the features of the preserved erosion surface developed on the Michigamme slate.

Conclusion

The writer suggests that moving ice is the most plausible explanation for the features described. This indicates glaciation in upper Michigan in either the late Precambrian or early Cambrian.

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